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GATE SOLVED PAPER - EE

2015-1

General Aptitude

Q. 1 - Q. 5 Carry one mark each.

Q. 1 Which of the following combinations is incorrect?

(A) Acquiescence – Submission

(B) Wheedle – Roundabout

(C) Flippancy – Lightness

(D) Profligate – Extravagant

Sol. 1 Correct option is (B).

Acquiescence – Acceptance without protect

Submission – The Act of submitting

Wheedle – Influence and arguing by gentle urging, caressing as flattering.

Round about – Deviation from a straight course

Flippancy – Inappropriate lavite (light mindedness)

Lightness – Having a light

Profligate – A dissolute men in fashionable society

Extravagant – Recklessly wasteful

So, the pair *Wheedle – Roundabout* is not synonym.

Q. 2 Given Set A $=\{2,3,4,5\}$ and Set B $=\{11,12,13,14,15\}$, two numbers are randomly selected, one from each set. What is probability that the sum of the two numbers equals 16?

(A) 0.20 (B) 0.25

(C) 0.30 (D) 0.33

Sol. 2 Correct option is (A).

Given

$$\text{Set } A = \{2,3,4,5\}$$

$$\text{Set } B = \{11,12,13,14,15\}$$

Two numbers are chosen, one from set A and other from set B. Then,

$$\text{Total} = 4 \times 5 = 20 \text{ cases}$$

Favourable case- Sum of two numbers equals 16.

$$\{(5,11),(4,12),(3,13),(2,14)\}$$

i.e. number of favourable cases $= 4$

Hence,
$$P = \frac{\text{Favourable case}}{\text{Total case}}$$

$$= \frac{4}{20} = 0.20$$

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Q. 3 Which of the following options is the closest in meaning to the sentence below?
She enjoyed herself immensely at the party.

(A) She had a terrible time at the party.

(B) She had a horrible time at the party.

(C) She had a terrific time at the party.

(D) She had a terrifying time at the party.

Sol. 3 Correct option is (C).
She enjoyed herself immensely at the party.
Here immensely means *to an exceedingly great extent or degree.*
Similar sentence is given in option (C)
She had a terrific time at the parts terrific
Here, terrific means *very great or intense, extraordinary good or great.*
However, the statements given in other options, give a different meaning as described below.
Option (A)
Terrible means *causing fear or dread as terror.*
Option (B)
Horrible means *a thing that causes horror.*
Option (C)
Terrifying means *causing extreme terror.*

Q. 4 Based on the given statements, select the most appropriate option to solve the given question.
If two floors in a certain building are 9 feet apart, how many steps are there in a set of stairs that extends from the first floor to the second floor of the building?
Statements:

(I) Each step is $\frac{3}{4}$ foot high.

(II) Each step is 1 foot wide.

(A) Statement I alone is sufficient, but statement II alone is not sufficient.

(B) Statement II alone is sufficient, but statement I alone is not sufficient.

(C) Both statements together are sufficient, but neither statement alone is sufficient.

(D) Statement I and II together are not sufficient.

Sol. 4 Correct option is (A).
Given

Distance between two floors of building = 9 feet

Height of each step $= \frac{3}{4}$ (Statement I)

Width of each step $= 1$ (Statement II)

Using the data give in statement I, we may calculate the number of steps in a set of stairs as

$$n = \frac{9}{3} \times 4 = 12 \text{ step}$$

So, statement I is sufficient to give the answer.
However, there is no use of width given in statement II to calculate number of required steps in set of stairs. So, width of foot can be anything, and it is not sufficient to obtain the number of steps.

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Thus, statement I alone is sufficient, but statement II alone is not sufficient.

Q. 5 Didn't you buy _____ when you went shopping ?

(A) any paper (B) much paper

(C) no paper (D) a few paper

Sol. 5 Correct option is (A).

The given sentence is interro-negative, and with interro-negative sentence *any* is used. So, the complete sentence will be

Didn't you buy any paper when you went shopping ?

Q. 6 - Q. 10 Carry two marks each.

Q. 6 The given statement is followed by some course of action. Assuming the statement to be true, decide the correct option.

Statement:

There has been a signification drop in the water level in the lakes supplying water to the city.

Course of action:

(I) The water supply authority should impose a partial cut in supply to tackle the situation.

(II) The government should appeal to all the residents through mass media for minimal use of water.

(III) The government should ban the water supply in lower areas.

(A) Statements I and II follow.

(B) Statements I and III follow.

(C) Statements II and III follow.

(D) All statements follow.

Sol. 6 Correct option is (A).

Since, there is significant drop in water level in the lakes, so to reduce the misuse of water, the course of action may be any of the following:

I the water authority should impose a partial cut in supply to tackle the situation.

II government should appeal to all the resident through mass media for minimal use of water.

However, the following course of action does not apply:

III The government should ban the water supply in lower areas.

Q. 7 The number of students in a class who have answered correctly. wrongly, or not attempted each questions in an exam, are listed in the table below. The marks for each question are also listed. There is no negative or partial marking.

Q. No.	Marks	Answered Correctly	Answered Wrongly	Not Attempted
1	2	21	17	6
2	3	15	27	2
3	1	11	29	4

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Q. No.	Marks	Answered Correctly	Answered Wrongly	Not Attempted
4	2	23	18	3
5	5	31	12	1

What is the average of the marks obtained by the class in the examination?

(A) 2.290 (B) 2.970

(C) 6.795 (D) 8.795

Sol. 7 Correct option is (B).

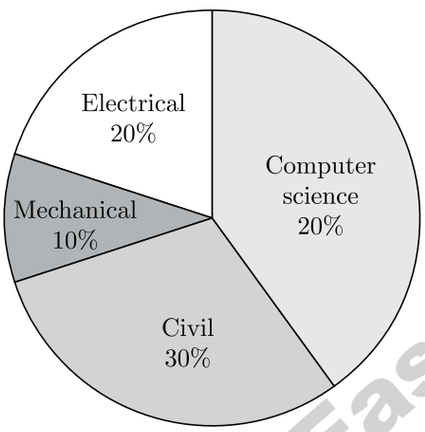
Average marks of the class in the examination is

$$= \frac{\text{total marks obtained}}{\text{total number of student}}$$

$$= \frac{21 \times 2 + 15 \times 3 + 11 \times 1 + 23 \times 2 + 31 \times 5}{0.47}$$

$$= 6.795$$

Q. 8 The pie chart below has the breakup of the number of students from different departments in an engineering college for the year 2012. The proportion of male to female students in each department is 5:4. There are 40 males in Electrical Engineering. What is the difference between numbers of female students in the Civil department and the female students in the Mechanical department?



Sol. 8 Correct answer is 32.

From pie-chart, we have

Total electrical student = 20%

The total student for which the data is given in pie chart is

Total number of students $= 20 + 20 + 10 + 30 = 80$

Electrical female student $= \frac{4}{5} \times 40 = 32$

Total electrical student = 72

Difference between female student of civil and mechanical is

$$= 30 - 10 = 20\%$$

This percentage value is the same as that of electrical students in given pie chart. So, the difference between female student of civil and mechanical is 32.

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Q. 9 Select the alternative meaning of the underlined part of the sentence.
The chain snatchers took to their heels when the police party arrived.
(A) took shelter in a thick jungle
(B) open indiscriminate fire
(C) took to flight
(D) unconditionally surrendered

Sol. 9 Correct option is (C).

Q. 10 The probabilities that a student passes in Mathematics, Physics and Chemistry are m, p, and c respectively. Of these subjects, the subjects has 75% chance of passing in at least one, a 50% chance of passing in at least two and a 40% chance of passing in exactly two.
Following relations are drawn in m, p, c:
(I) $p + m + c = \frac{27}{20}$
(II) $p + m + c = \frac{13}{20}$
(III) $(p) \times (m) \times (c) = \frac{1}{10}$
(A) Only relation I is true.
(B) Only relation II is true.
(C) Relations II and III are true.
(D) Relations I and III are true.

Sol. 10 Correct option is (D).

END OF THE QUESTION PAPER

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Electrical Engineering

Q. 1 - Q. 25 Carry one mark each.

Q. 1 A moving average function is given by $y(t)=\frac{1}{T}\int_{t-T}^{t}u(\tau)dt$. If the input u is a sinusoidal signal of frequency $\frac{1}{2T}$ Hz, then in steady state, the output y will lag u (in degree) by _____

Sol. 1 Correct answer is 90.

$$y(t)=\frac{1}{T}\int_{t-T}^{t}u(\tau)\,dt$$

$$\omega=2\pi f=2\pi\times\frac{\pi}{T}=\omega T=\pi$$

$$u(t)=\sin\omega t \qquad \text{(given in question)}$$

$$y(t)=\frac{1}{T}\int_{t-T}^{t}\sin(\omega\tau)\,d\tau$$

$$=\frac{1}{\omega T}\cos(\omega\tau)\Big|_{t}^{t-T}$$

$$=\frac{1}{\pi}[\cos\omega(t-T)-\cos\omega t]$$

$$=\frac{1}{\pi}[\cos\omega t\cos\omega T+\sin\omega t\sin\omega T-\cos\omega t]$$

$$=\frac{1}{\pi}[\cos\omega t+\cos\pi+\sin\omega+\sin\pi-\cos\omega t]$$

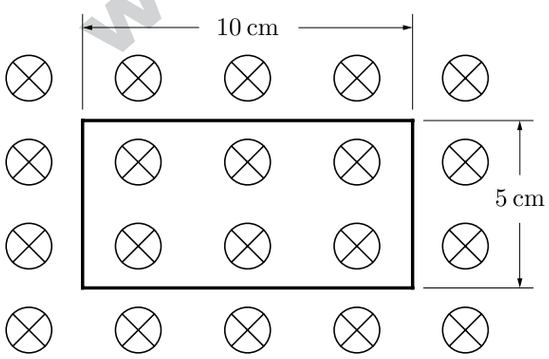
$$=\frac{1}{\pi}[-2\cos\omega t]$$

$$=\frac{+2}{\pi}\sin(\omega t+90^\circ)$$

$$\phi=90^\circ$$

Hence, output lags by 90°.

Q. 2 Consider a one-turn rectangular loop of wire place in a uniform magnetic field as shown in the figure. The plane of the loop is perpendicular to the field lines. The resistance of the loop is $0.4\,\Omega$, and its inductance is negligible. The magnetic flux density (in Tesla) is a function of time, and is given by $B(t)=0.25\sin\omega t$, where $\omega=2\pi\times 50$ radian/second. The power absorbed (in Watt) by the loop from the magnetic field is _____



Sol. 2 Correct answer is 0.192

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By using power eqn. $P_{abs} = \dfrac{V^2}{R}$

By Faraday law, $V_{emf} = \dfrac{-d\psi}{dt}$

$$\psi = \int B.ds = \int 0.25 \sin \omega t ds$$

$$\psi = 0.25 \times \sin \omega t \times 10 \times 5 \times 10^{-4}$$

$$V_{emf} = \frac{-d\psi}{dt}$$

$$= 0.25 \times 10 \times 5 \times 10^{-4} \cos \omega t \cdot \omega$$

$$= -\frac{1}{8}\pi \cos \omega t$$

So, power absorbed is $P = \dfrac{V^2}{R}$

$$P = \frac{1}{64}\pi^2 \cos^2 \omega t$$

So, $$P_{\text{avg}} = \frac{1}{2\pi}\int_0^{2\pi} \frac{1}{64}\pi^2 \cos^2 \omega t d(\omega t)$$

$$= \frac{1}{2\pi}\left[\int_0^{2\pi} \frac{1}{64}\pi^2 \frac{(1-\cos 2\omega t)}{2} d(\omega t)\right]$$

$$= \frac{1}{2\pi}\frac{1}{64}\pi^2 \frac{1}{2} \times 2\pi$$

$$P_{\text{avg}} = 0.192 \text{ W}$$

Q. 3 If the sum of the diagonal elements of a 2×2 matrix is -6, then the maximum possible value of determinant of the matrix is_____

Sol. 3 Correct answer is 9.

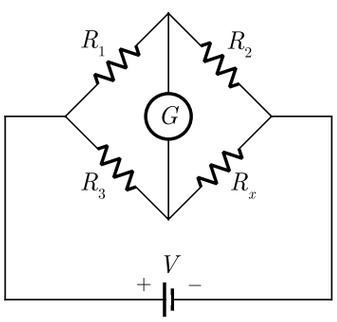
Sum of diagonal element of matrix is -6, and the matrix is (2×2). So, we have the possible combinations as

$(-1,-5)$, $(-5,-1)$, $(-8,2)$, $(-2,-3)$, $(-4,-2)$, $(-9,3)$, $(-3,-1)$, $(-3,-3)$, $(-10,4)$.

Now, we have to obtain maximum value of determinant, it means both the number must have same sign. There is no combination of two positive numbers, so we take the combination of two negative values. The maximum possible determinant is obtained as

$$-3 \times -3 = 9$$

Q. 4 When the Wheatstone bridge shown in used to find value of resistance R_x , the Galvanometer G indicates zero current when $R_1 = 50\,\Omega$, $R_2 = 65\,\Omega$ and $R_3 = 100\,\Omega$. If R_3 is known with $\pm 5\%$ tolerance on its nominal value of $100\,\Omega$, what is range of R_x in ohms?



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(A) [123.5, 136.5] (B) [125.898, 134.12]

(C) [117, 143] (D) [120.25, 139.75]

Sol. 4 Correct option is (A).

For balanced Wheatstone bridge, we have

$$\frac{R_x}{R_2} = \frac{R_3}{R_1}$$

or $$R_x = R_3\frac{R_2}{R_1}$$

Given $$R_2 = 65$$

$$R_1 = 50$$

$$R_3 = 100 \pm 5\% = 95\,\Omega \text{ or } 105\,\Omega$$

So, $$R_x = R_3\frac{R_2}{R_1}$$

$$= 95 \times \frac{65}{50} \quad \text{(substituting minimum value)}$$

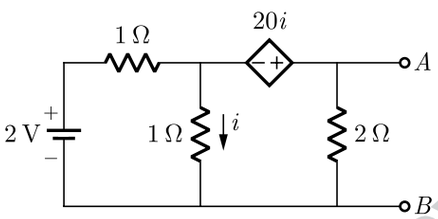
$$= 123.5\,\Omega$$

Hence, $$R_x = R_3\frac{R_2}{R_1}$$

$$= 105 \times \frac{65}{50} \quad \text{(substituting maximum value)}$$

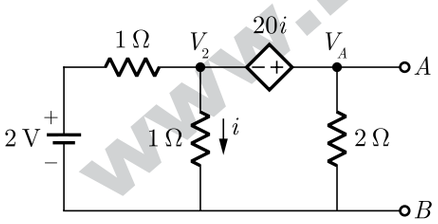
$$= 136.5\,\Omega$$

Q. 5 For the given circuit the Thevenin equivalent is to be determined. The Thevenin voltage, V_{Th} (in volt), seen from terminal AB is _____



Sol. 5 Correct answer is 3.36

We have the given circuit



Here, we use nodal analysis to obtain the Thevenin voltage.

Let voltage at node $A = V_A$ Volt

and voltage at node $B = 0$ Volt

So, we may write

$$\frac{V_A - 0}{2} + \frac{V_2 - 0}{1} + \frac{V_2 - 2}{1} = 0$$

$$V_A + 2V_2 + 2V_2 - 4 = 0$$

$$V_A + 4V_2 - 4 = 0 \quad (1)$$

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Again, we have

$$V_2 + 20i = V_A$$

or $$V_2 + 20\,V_2 = V_A \qquad \left(i = \frac{V_2 - 0}{1}\right)$$

or $$21\,V_2 = V_A \qquad (2)$$

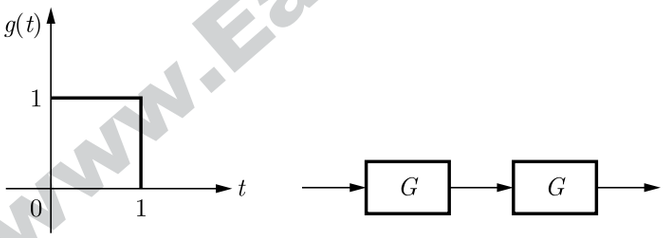
Substituting this result in equation (1), we get

$$V_A + \frac{4\,V_A}{21} = 4$$

or $$25\,V_A = 21 \times 4$$

Hence, $$V_A = \frac{84}{25} = 3.36 \text{ V}$$

Q. 6 The impulse response $g(t)$ of a system, G, is as shown in Figure (a). What is the maximum value attained by the impulse response of two cascaded blocks of G as shown in Figure (b)?



(a) (b)

(A) $\frac{2}{3}$

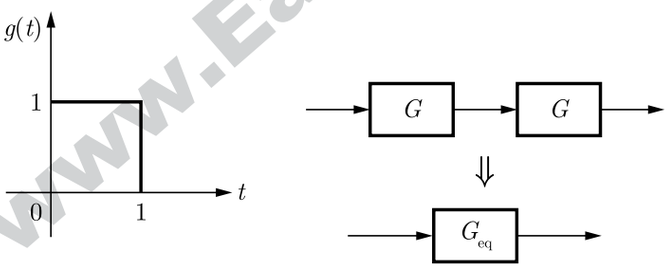
(B) $\frac{3}{4}$

(C) $\frac{4}{5}$

(D) 1

Sol. 6 Correct option is (D).

The given system is



The continuous time signal is defined as

$$g(t) = u(t) - u(t-1)$$

By convolving G with G itself, we get

$$g(t) * g(t) = [u(t) - u(t-1)] \times [u(t) - u(t-1)]$$

$$= u(t) * u(t) - u(t) * u(t-1) - u(t-1) * u(t) + u(t-1) * 4(t-1)$$

$$= r(t) - r(t-1) - r(t-1) + r(t-2)$$

So, $$g(t)_{eq} = r(t) - 2r(t-1) + r(t-2)$$

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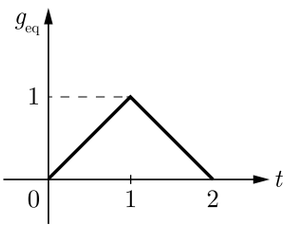
The continuous time signal is drawn in the figure below.



Hence, maximum value of g_{eq} is equal to 1.

Q. 7 Base load power plants are
P: wind farms.
Q: run-of-river plants.
R: nuclear power plants.
S: diesel power plants.
(A) P, Q and S only (B) P, R and S only
(C) P, Q and R only (D) Q and R only

Sol. 7 Correct option is (D).
Base load plants are those plants which supply power for 24 hours. So nuclear, thermal and hydro plant (which runs by water of river) are in the category of Base load.
Peak load plant are those plants which supply power on peak time, like diesel plant, renewable energy developed plant. So, in this category wind, diesel are included.

Q. 8 Of the four characteristic given below, which are the major requirements for an instrumentation amplifier?
P: High common mode rejection ratio
Q: High input impedance
R: High linearity
S: High output impedance
(A) P, Q and R only (B) P and R only
(C) P, Q and S only (D) Q, R and S only

Sol. 8 Correct option is (A).
Characteristic of instrument amplifier is
1. High input impedance
2. High input impedance
3. Low output impedance.

Hence, in the given problem, option (C) is wrong.

Q. 9 A random variable X has probability density function $f(x)$ as given below:

$$f(x) = \begin{cases} a + bx & \text{for } 0 < x < 1 \\ 0 & \text{otherwise} \end{cases}$$

If the expected value $E[X] = \frac{2}{3}$, then $\Pr[X < 0.5]$ is _____

Sol. 9 Correct answer is 0.25
Given

$$f(x) = \begin{cases} a + bx & 0 < x < 1 \\ 0 & \text{other wise} \end{cases}$$

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Sum of total probability is 1, i.e.

$$\int_{-\infty}^{\infty} f(x)\,dx = 1$$

or $$\int_{-0}^{1} (a+bx)\,dx = 1$$

or $$ax + b\frac{x^2}{2}\Big|_{x=0}^{x=1} - a + \frac{b}{2} = 1 \qquad (1)$$

Again, we have

$$E(x) = \frac{2}{3}$$

or $$\int_{0}^{1} xf(x)\,dx = \frac{2}{3}$$

or $$\int_{0}^{1} x(a+bx)\,dx = \frac{2}{3}$$

or $$\frac{a}{2}x^2 + \frac{6\times 3}{3}\Big|_{x=0}^{x=1} = \frac{2}{3} \qquad (2)$$

Solving equations (1) and (2), we get

$$a = 0 \;\; b = 2$$

Hence, $$\Pr(X < 0.5) = \int_{x=-\infty}^{0.5} f(x)\,dx$$

$$= \int_{-\infty}^{0} f(x)\,dx f \int_{0}^{0.5} 2x\,dx$$

$$= 0 + \frac{2x^2}{2}\Big|_{x=0}^{x=0.5}$$

$$= (0.5)^2 = 0.25$$

Q. 10 Consider a function $\overline{f} = \frac{1}{r^2}\hat{r}$, where r is the distance from the origin and $\hat{r}$ is the unit vector in the radial direction. The divergence of the function over a sphere of radius R, which includes the origin, is

(A) 0

(B) 2π

(C) 4π

(D) $R\pi$

Sol. 10 Correct option is (A).

Given $$\overline{f} = \frac{1}{r^2}\overline{r}$$

Here $\overline{r}$ is the unit vector in the radial direction. So, divergence of F is equal to $\overline{\nabla} \cdot \overline{F}$, given by

$$\overline{\nabla} \cdot \overline{F} = \frac{1}{r^2}\frac{d}{\partial r}(r^2 F_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta F_\theta) + \frac{1}{r\sin\theta}\frac{\partial F_\theta}{\partial \phi}$$

$$= \frac{1}{r^2}\frac{\partial}{\partial r}\left(r + \frac{1}{r^2}\right)$$

$$= \frac{1}{r^2}\frac{\partial}{\partial r}$$

Hence, $$\overline{\nabla} \cdot \overline{F} = 0$$

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Q. 11 A separately excited DC generator has an armature resistance of $0.1\,\Omega$ and negligible armature inductance. At rated field current and rated rotor speed, its open-circuit voltage is 200 V. When this generator is operated at half the rated speed, with half the rated field current, an uncharged $1000\,\mu F$ capacitor is suddenly connected across the armature terminals. Assume that the speed remains unchanged during the transient. At what time (in microsecond) after the capacitor is connected will the voltage across it reach 25 V?

(A) 62.25 (B) 69.3

(C) 73.25 (D) 77.3

Sol. 11 Correct option is (B).

Separately excited d.c. generators has

$$r_a = 0.1\,\Omega$$

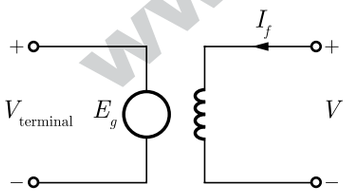
Open circuit voltage is

$$= E_1 = 200\text{ V at rated speed}$$

When generator is rotated at half the rated speed and half the field current. So,

$$\phi_2 = 0.5\phi_1$$

$$N_2 = 0.5N_1$$



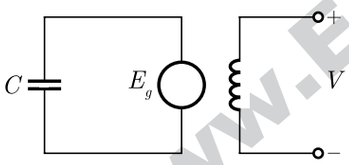
Now, $E \propto \phi N$

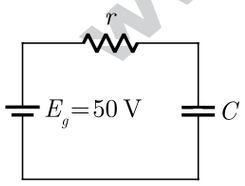
So, $\dfrac{E_1}{E_2} = \dfrac{\phi_1 N_1}{\phi_2 N_2}$

or $\dfrac{200}{E_2} = \dfrac{\phi_1 \times N_1}{0.5\phi_1 \times 0.5N_1}$

or $E_2 = 50\text{ V}$

If a capacitor is connected, so new circuit becomes as





Therefore, $V = V_0(1 - e^{-t/RC})$

or $25 = 50(1 - e^{-t/(0.1 \times 1000 \times 10^{-6})})$

or $t = 69.3\,\mu\text{sec}$

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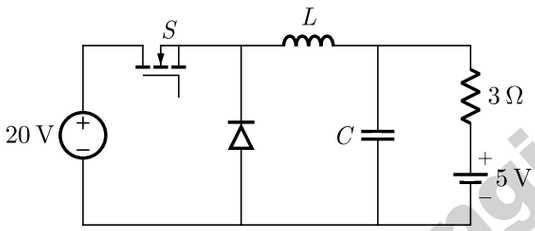
Q. 12 In the following chopper, the duty ratio of switch S is 0.4. If the inductor and capacitor are sufficiently large to ensure continuous inductor current and ripple free capacitor voltage, the charging current (in Ampere) of the 5 V battery, under steady-state, is_ _ _ _ _ _



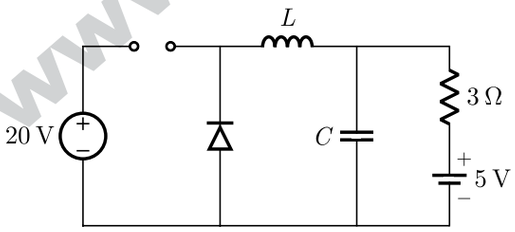
Sol. 12 Correct answer is 1.

Duty ratio of switch S is

$$\frac{T_{ON}}{T} = 0.4$$

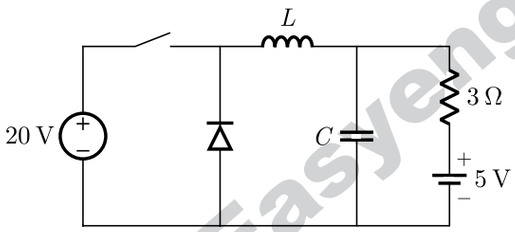
We have to determine the charging current of 5V battery.

During T_{ON}, circuit looks like



So, voltage across capacitor is $= 20$ V

Again, during T_{OFF} circuit looks like



Voltage across capacitor $= 0$ V

So, average output voltage is

$$V_0 = dV_s = 0.4 \times 10 = 8 \text{ V}$$

and

$$I_0 = \frac{V_0 - E}{R} = \frac{8-5}{3} = 1 \text{ A}$$

Q. 13 If a continuous function $f(x)$ does not have a root in the interval $[a, b]$, then which one of the following statements is TRUE?

(A) $f(a) \cdot f(b) = 0$

(B) $f(a) \cdot f(b) < 0$

(C) $f(a) \cdot f(b) > 0$

(D) $f(a)/f(b) \leq 0$

Sol. 13 Correct option is (C).

Given that $f(x)$ is continuous function, and doesn't have any root in $[a, b]$. So, function is either positive or negative in $[a, b]$. Now, we consider the two cases.

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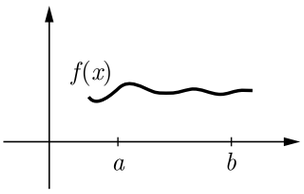
CASE I

If $f(x)$ has all positive values in the interval $[a, b]$ as shown in figure, then

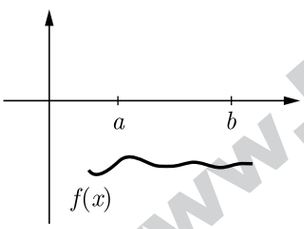
$$f(a) \cdot f(b) > 0$$



CASE II

Again, for the given interval (a, b), if $f(x)$ has all negative values then

$$f(a) \cdot f(b) > 0$$



Hence, for both the cases, we have

$$f(a) \cdot f(b) > 0$$

Thus, we may conclude the following results.

If $f(x)$ have any root in $[a, b]$, then

$$f(a) \cdot f(b) < 0$$

If $f(x)$ does not have root in $[a, b]$, then

$$f(a) \cdot f(b) > 0$$

Q. 14 The primary mmf is least affected by the secondary terminal conditions in a

(A) power transformer

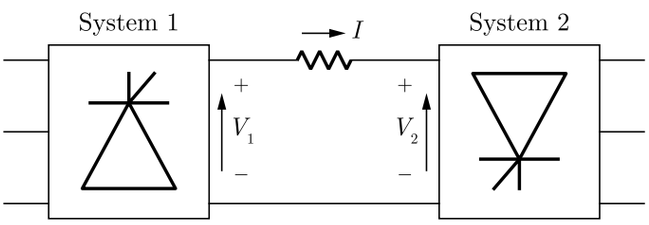
(B) potential transformer

(C) current transformer

(D) distribution transformer

Sol. 14 Correct option is (B).

Q. 15 Consider a HVDC link which uses thyristor based line–commutated converters as shown in the figure. For a power flow of 750 MW from system 1 to system 2, the voltages at the two ends, and the current, are given by: $V_1 = 500$ kV, $V_2 = 485$ kV and $I = 1.5$ kA. If the direction of power flow is to be reversed (that is, from system 2 to system 1) without changing the electrical connection, then which one of the following combinations id feasible?



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If power is to be reversed

(A) $V_1 = -500$ kV, $V_2 = -485$ kV and $I = 1.5$ kA

(B) $V_1 = -485$ kV, $V_2 = -500$ kV and $I = 1.5$ kA

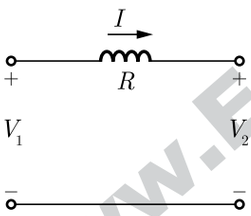
(C) $V_1 = 500$ kV, $V_2 = 485$ kV and $I = -1.5$ kA

(D) $V_1 = -500$ kV, $V_2 = -485$ kV, $I = -1.5$ kA

Sol. 15 Correct option is (A).

In the rectifier system, direction of current can not be changed, because in the thyristor, reverse conduction is not possible. So, for changing direction of power, voltage sign can be changed. So, we have

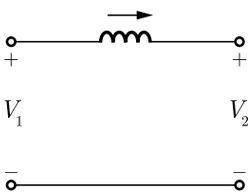
$$I = \frac{V_1 - V_2}{R}$$



For power to be transferred reverse,

$$I = \frac{V_1 - V_2}{R}$$

This current should be positive

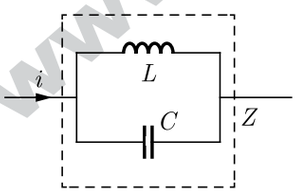


For transferring reverse power voltage sign should be reversed. For current to be positive, and same amount of power in the reverse direction, the possible values are

$$V_1 = -485 \text{ kV}$$

and $$V_2 = -500 \text{ kV}$$

Q. 16 An inductor is connected in parallel with a capacitor as shown in the figure.



As the frequency of current i is increased, the impedance (Z) of the network varies as

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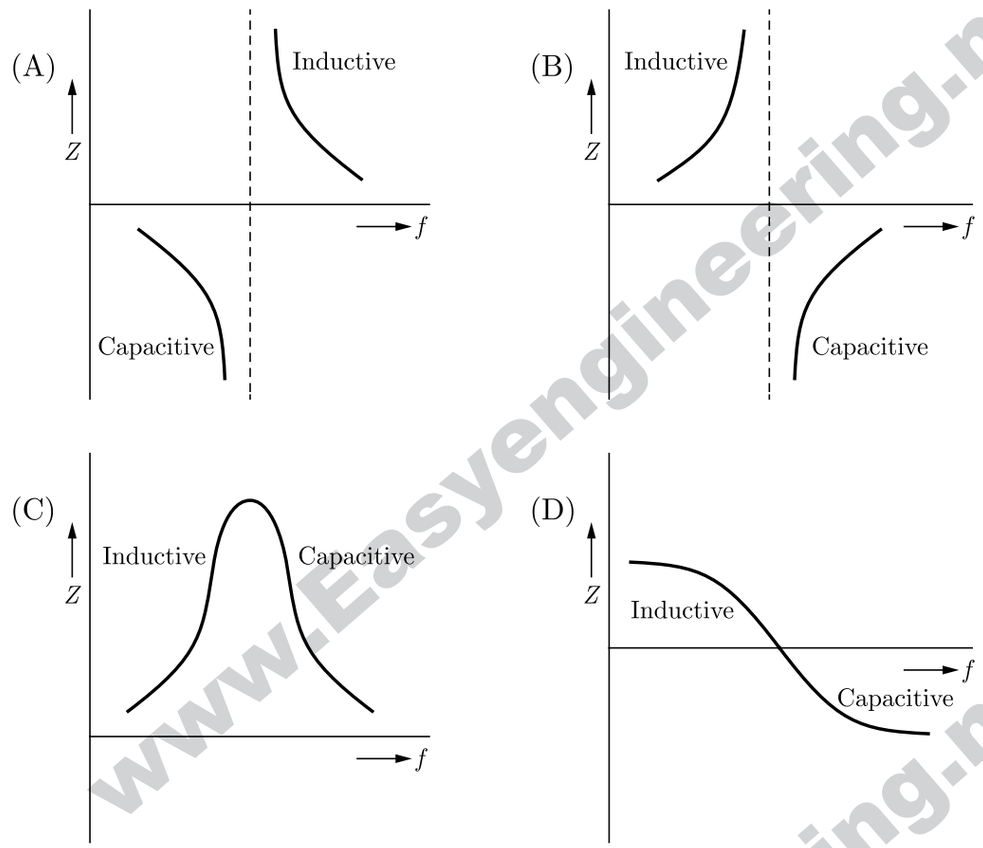

Sol. 16 Correct option is (B).

Total impedance of the tank circuit is

$$Z_{eq} = \frac{Z_L Z_C}{Z_L + Z_C}$$

$$= \frac{j\omega L \cdot \frac{1}{j\omega C}}{j\omega L + \frac{1}{j\omega C}}$$

$$= \frac{\frac{L}{C} \times j\omega C}{-\omega^2 LC + 1}$$

$$Z = \left(\frac{j\omega L}{1 - \omega^2 LC}\right)$$

$$Z = \frac{j\omega L}{1 - \omega^2 LC}$$

At $\omega^2 LC = 1$

or $\omega = \frac{1}{\sqrt{LC}}$

or $f_1 = \frac{1}{2\pi\sqrt{LC}}$

The value of impedance is infinite.

For $f < f_1$, the impedance is increasing; and for $f > f_2$, impedance is decreasing in magnitude. Hence, we draw impedance (Z) vs frequency (f) graph as

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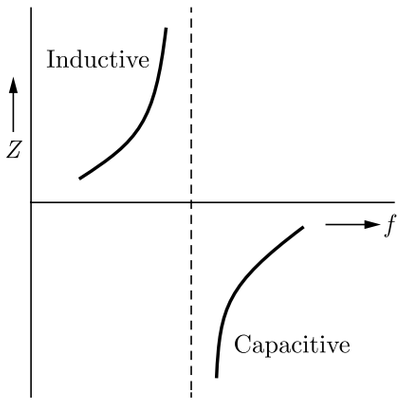
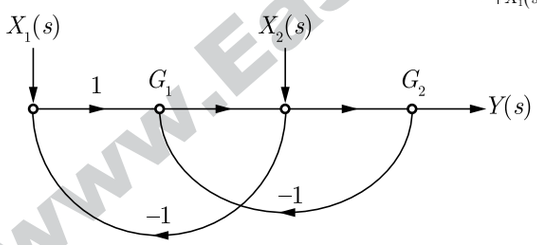


Q. 17 For the signal-flow graph shown in the figure, which one of the following expression is equal to the transfer function $\left.\frac{Y(s)}{X_2(s)}\right|_{X_1(s)=0}$?



(A) $\dfrac{G}{1+G_2(1+G_1)}$

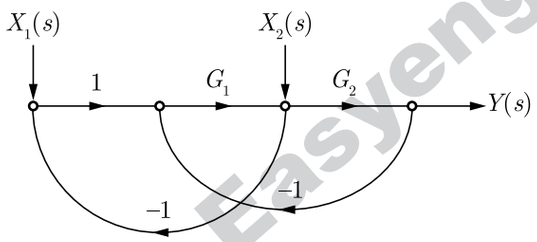
(B) $\dfrac{G_2}{1+G_1(1+G_2)}$

(C) $\dfrac{G_1}{1+G_1G_2}$

(D) $\dfrac{G_2}{1+G_1G_2}$

Sol. 17 Correct option is (A).

Given signal flow graph is



By Mason's formula, we obtain

$$\text{T.F.} = \frac{p_k\,\Delta_k}{\Delta}$$

where

$\Delta = 1 - \sum(\text{loop gains}) + \sum(\text{nontouching loop gains taken two at a time}) + ..$

$p_k = k_{\text{th}}$ forward path gain

$\Delta_k = \Delta$ for the part of SFG that is non-touching with the k_{th} forward path

If $X_1(s) = 0$, then

$$\Delta = 1 - (-G_1G_2 - G_1) = 1 + G_1G_2 + G_1$$

and forward path is

$$p_1 = G_2$$

$$\Delta_1 = 1 - (0) = 1$$

Hence, we get

$$\text{T.F.} = \frac{p_1\,\Delta_1}{\Delta} = \frac{G_2}{1+G_1(1+G_2)}$$

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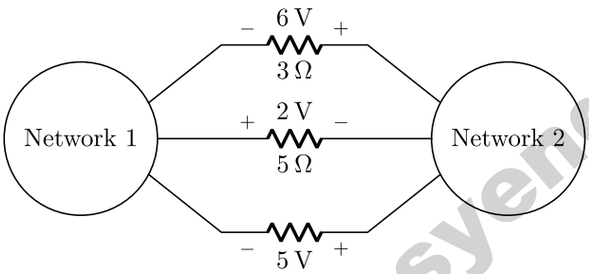
$$= \frac{G_2}{1 + G_1(1 + G_2)}$$

Q. 18 The voltages developed across the 3 Ω and 2 Ω resistors shown in the figure are 6 V and 2 V respectively, with the polarity as marked. What is the power (in Watt) delivered by the 5 V voltage source?

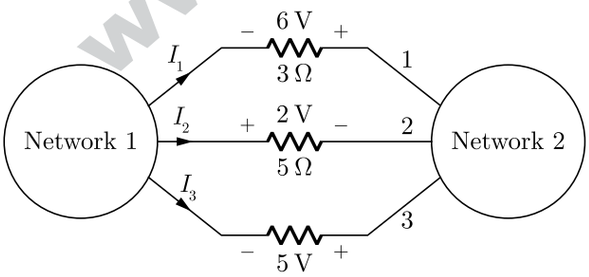


(A) 5 (B) 7

(C) 10 (D) 14

Sol. 18 Correct option is (A).

Given system is



Current through branch 1 is

$$I_1 = \frac{-6}{3} = -2 \text{ A}$$

Current through branch 2 is

$$I_2 = \frac{2}{2} = 1 \text{ A}$$

So, current through branch 3 is

$$I_3 = I_1 + I_2$$
$$= -2 + 1 = -1 \text{ A}$$

Hence, Power $= 5 \times 1 = 5$ Watt

Q. 19 The self inductance of the primary winding of a single phase, 50 Hz, transformer is 800 mH, and that of the secondary winding is 600 mH. The mutual inductance between these tow windings is 480 mH. The secondary winding of this transformer is short circuited and the primary winding is connected to a 50 Hz, single phase, sinusoidal voltage source. The current flowing in both the winding is less than their respective rated currents. The resistance of both windings can be neglected. In this connection, what is the effective inductance (in mH) seen by the source?

(A) 416 (B) 440

(C) 200 (D) 920

Sol. 19 Correct option is (A).

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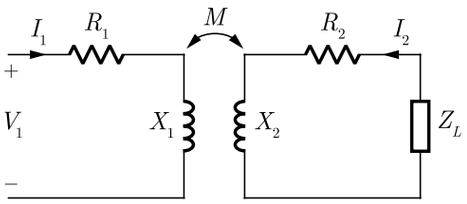
Consider the transformer circuit shown below.



For the circuit, we have

$$Z_{in} = \text{input impedance as seen by source}$$

or $$Z_{in} = \frac{V_1}{I_1} = (R_1 + jX_1) + \frac{\omega^2 M^2}{R_2 + jX_2 + Z_L}$$

By neglecting resistances R_1 and R_2, we get

$$Z_{in} = \frac{V_1}{I_1} = jX_1 + \frac{\omega^2 M^2}{jX_2 + Z_L}$$

$$= jX_1 - j\frac{\omega^2 M^2}{X_2}$$

$$= j\left(X_1 - \frac{\omega^2 M^2}{X_2}\right)$$

$$= j\left(\omega L_1 - \frac{\omega^2 M^2}{\omega L_2}\right)$$

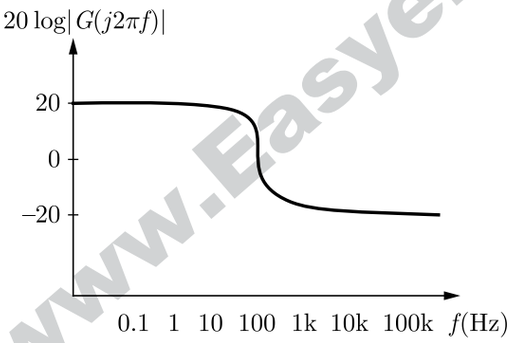
$$= j\left(314 \times 0.8 - \frac{314^2 \times 0.48^2}{0.6 \times 314}\right)$$

$$= j\,130.744$$

$$j\omega L_{eff} = j\,130.744$$

Hence, $$L_{eff} = 416 \text{ mH}$$

Q. 20 A Bode magnitude plot for the transfer function $G(s)$ of a plant is shown in the figure. Which one of the following transfer functions best describes the plant?



(A) $\dfrac{1000(s+10)}{s+1000}$

(B) $\dfrac{10(s+10)}{s(s+1000)}$

(C) $\dfrac{s+1000}{10s(s+10)}$

(D) $\dfrac{s+1000}{10(s+10)}$

Sol. 20 Correct option is (D).

We may redraw the given Bode plot in its ideal form as

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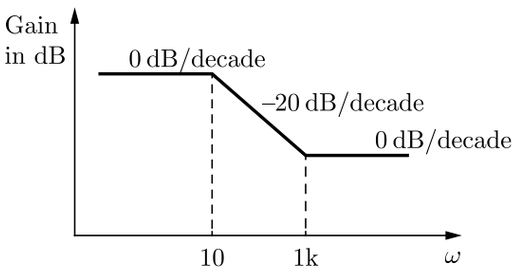


At $\omega = 10$ rad/see slope is decreasing by 20 dB/decade, so it is a pole.

At $\omega = 1$ k rad/sec, slope is again increase to 0 dB/decade, so it is a zero.

Therefore,

$$G(s) = \frac{k(I + T_2 s)}{(1 + T_1 s)} = \frac{k\left(1 + \frac{1}{1000} s\right)}{\left(1 + \frac{1}{10} s\right)} \quad (1)$$

Initially, gain is 20 dB. So, we have

$$\left|G(j\omega)\right|_{at\ \omega = 0} = \frac{k(1+10)}{(1 + 0 \times \tau_1)}$$

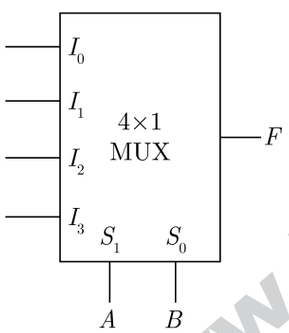
or $20 \log_{10} k = 20$ $\qquad 20 \log_{10} \left|G(j\omega)\right| = 20$

$$k = 10$$

By substituting value of k in equation (1), we get

$$G(s) = \frac{(s + 1000)}{10(s + 10)}$$

Q. 21 In the 4×1 multiplexer, the output F is given by $F = A \oplus B$, Find the required input '$I_3 I_2 I_1 I_0$'.



(A) 1010 (B) 0110

(C) 1000 (D) 1110

Sol. 21 Correct option is (B).

Given that the output of multiplexer is

$$F = A \oplus B = A'B + AB' \quad (1)$$

Truth table for the multiplexer is obtained as

S_1	S_0	F
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

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From the truth table, we have

$$F = I_0\overline{S_0}\,\overline{S_1} + \overline{I_1}S_0\overline{S_1} + I_2S_1\overline{S_0} + I_3S_1S_0$$
$$= I_0\overline{B}\;\overline{A} + I_1B\overline{A} + I_2A\overline{B} + I_3AB \qquad (S_0 = B,\ S_1 = A)$$

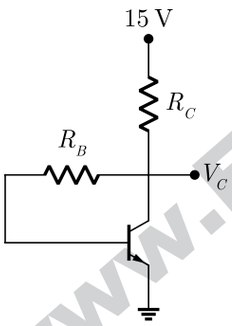
Comparing the above expression to equation (1), we get

$$I_0 = 0,\ I_1 = 1,\ I_2 = 1, \text{ and } I_3 = 0$$

Hence, the required input is

$$`I_3I_2I_1I_0' = 0110$$

Q. 22 In the given circuit, the silicon transistor has $\beta = 75$ and collector voltage $V_C = 9$ V. Then the ratio of R_B and R_C is_____

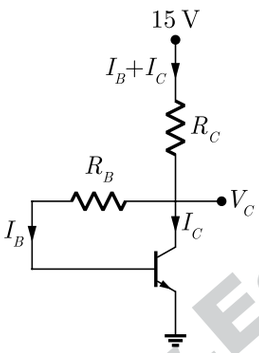


Sol. 22 Correct answer is 105.1

Given $\beta = 75$

$V_C = 9$ V

We redraw the given circuit as



From the circuit, we have

$$15 - R_C(I_C + I_B) = V_C$$
$$15 - V_C = R_C(I_C + I_B)$$
$$R_C(I_C + I_B) = 6 \text{ V} \qquad (1)$$

Applying Kirchoff's law across B-E Junction,

$$V_C - R_BI_B - V_{BC} = 0$$

or $$9 - 0.7 = R_BI_B$$

or $$R_BI_B = 8.3 \qquad (2)$$

Also, $$I_C = \beta I_B = 75I_B \qquad (3)$$

Solving equations (1), (2), and (3), we get

$$R_C(75+1)I_B = 6 \text{ V} \qquad (4)$$
$$R_BI_B = 8.3 \text{ V} \qquad (5)$$

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Hence, dividing equation (5) by (4), we obtain the desired ratio as

$$\frac{R_B}{R_C} \times \frac{1}{76} = \frac{8.3}{6}$$

or
$$\frac{R_B}{R_C} = \frac{8.3 \times 76}{6} = 105.1 \text{ V}$$

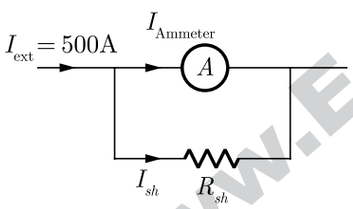
Q. 23 A (0-50 A) moving coil ammeter has a voltage drop of 0.1 V across its terminals at full scale deflection. The external shunt resistance (in miliohms) needed to extend its range to (0-500A) is_____

Sol. 23 Correct answer is 0.22

Given

Full scale deflection before adding resistance = 50 A

Voltage drop = 0.1 V



In the circuit, external current should be equal to sum of ammeter and shunt current, i.e.

$$I_{ext} = I_{Ammeter} + I_{sh}$$

or
$$500 = 50 + I_{sh}$$

or
$$I_{sh} = 450 \text{ A}$$

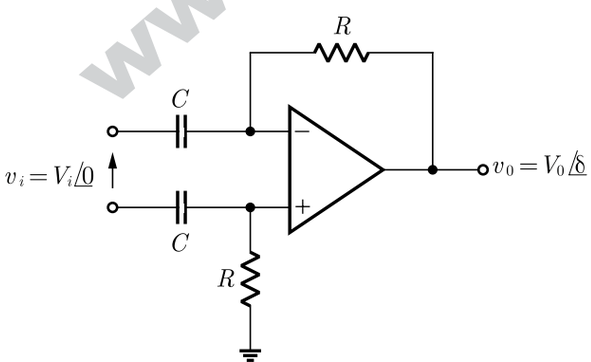
Again, voltage drop on both ammeter and shunt should be equal, i.e.

$$I_A \times R_A = I_{sh} R_{sh}$$

or
$$0.1 = 450 \times R_{sh}$$

Hence,
$$R_{sh} = \frac{0.1}{450} = 0.22 \text{ m}\Omega$$

Q. 24 Consider the circuit shown in the figure. In this circuit $R = 1\,\text{k}\Omega$ and $C = 1\,\mu\text{F}$. The input voltage is sinusoidal with a frequency of 50 Hz, represented as phasor with magnitude V_i and phase angle 0 radian as shown in the figure. The output voltage is represented as a phasor with magnitude V_0 and phase angle δ radian. What is the value of output phase angle δ (in radian) relative to the phase angle of the input voltage?



(A) 0

(B) π

(C) $\frac{\pi}{2}$

(D) $-\frac{\pi}{2}$

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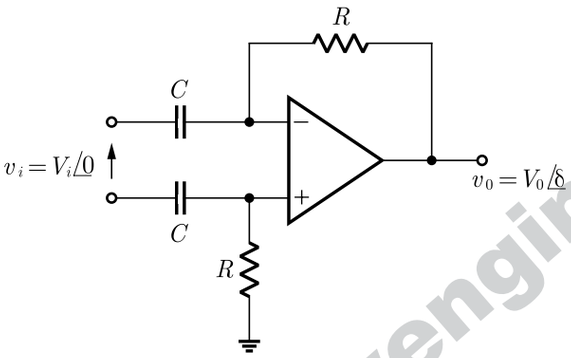
Sol. 24 Correct option is (A).

Given circuit is



By using node analysis, we can write the equation

$$\frac{0 - V_i}{\frac{1}{sC}} + \frac{0 - V_0 \angle \delta}{R} = 0$$

or $$-V_i \cdot sC - \frac{V_0 \angle \delta}{R} = 0$$

or $$V_0 \angle \delta = -RsCV_i$$

or $$V_0 \angle \delta = -RsCV_i \angle 0$$

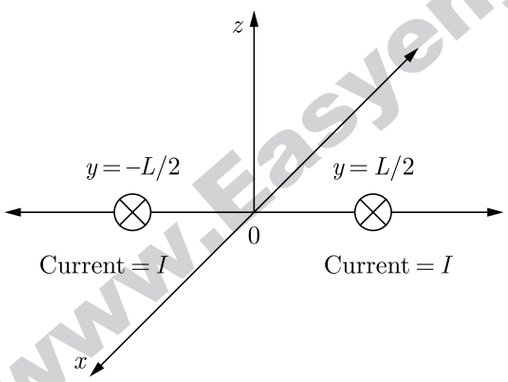
or $$V_0 \angle \delta = -RC j\omega V_i \angle 0 \qquad (s = j\omega)$$

or $$V_0 \angle \delta = RC\omega V_i \angle -90^\circ$$

Here, $RC\omega V_i$ is a real quantity, so we get

$$\delta = -90^\circ$$

Q. 25 A steady current I is flowing in the $-x$ direction through each of two infinitely long wires at $y = \pm \frac{L}{2}$ as shown in the figure. The permeability of the medium is μ_0. The $\overline{B}$-field at $(0, L, 0)$ is



(A) $-\frac{4\mu_0 I}{3\pi L}\hat{z}$

(B) $+\frac{4\mu_0 I}{3\pi L}\hat{z}$

(C) 0

(D) $-\frac{3\mu_0 I}{4\pi L}\hat{z}$

Sol. 25 Correct option is (A).

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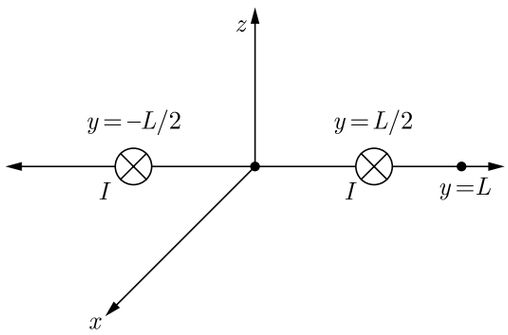

Magnitude of magnetic field at $Y = L$ is sum of magnetic field at $Y = -L/2$ and $Y = +L/2$, i.e.

$$\begin{aligned} B &= B_1 + B_2 \\ &= \frac{\mu_0 I}{2\pi\left(\frac{3L}{2}\right)} + \frac{\mu_0 I}{2\pi\left(\frac{L}{2}\right)} \qquad \left(B = \frac{\mu I}{2\pi d}\right) \\ &= \frac{-\mu_0 I}{2\pi L}\left[\frac{2}{3} + 2\right] \\ &= \frac{-\mu_0 I}{2\pi L}\left(\frac{6+2}{3}\right) \end{aligned}$$

Hence, $\vec{B} = \dfrac{-4\mu_0 I}{3\pi L}\hat{a}_z$

Q. 26 - Q. 55 Carry two marks each.

Q. 26 Consider a discrete time signal given by

$$x[n] = (-0.25)^n u[n] + (0.5)^n u[-n-1]$$

The region of convergence of its Z-transform would be

(A) the region inside the circle of radius 0.5 and centered at origin.

(B) the region outside the circle of radius 0.25 and centered at origin.

(C) the annular region between the two circles, both centered at origin and having radii 0.25 and 0.5.

(D) the entire z-plane.

Sol. 26 Correct option is (C).

Given discrete time signal,

$$x[n] = (-0.25)^n u(n) + (0.5)^n u(-n-1)$$

Here, we have two functions,

$$f_1 = (-0.25)^n u(n)$$

$$f_2 = (0.5)^n u(-n-1)$$

For first function, ROC is outside the circle with radius 0.25, i.e.

ROC 1: $|Z| > |0.25|$ (1)

Again, for second function, ROC is inside the circle with radius 0.5, i.e.

ROC 2: $|Z| < |0.5|$ (2)

Hence, the ROC of combined function is

$$\text{ROC} = 0.25 < |Z| < 0.5$$

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Q. 27 Two players, A and B, alternately keep rolling a fair dice. The person to get a six first wins the game. Given that player A starts the game, the probability that A wins the game is

(A) $\frac{5}{11}$ (B) $\frac{1}{2}$

(C) $\frac{7}{13}$ (D) $\frac{6}{11}$

Sol. 27 Correct option is (D).

Given that A and B play game alternately.

Probability of getting 6 on die is

$$= \frac{1}{6}$$

and probability of not getting 6 is

$$= \left(1 - \frac{1}{6}\right) = \frac{5}{6}$$

So, probability that A wins the game at first attempt is

$$= \frac{1}{6}$$

Again, we determine the probability that A wins the game in second chance. It can happen if 6 does not appear in the first chance of A, and again 6 does not appear in the first chance of B, and then 6 appears in the second chance of A. So, the probability is

$$= \frac{5}{6} \cdot \frac{5}{6} \cdot \frac{1}{6}$$

Hence, the net probability, that A wins the game, is given by

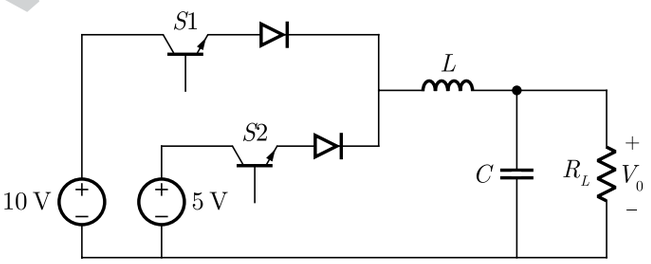
$$= P(A) + P(\overline{A})P(\overline{B})P(A) + P(\overline{A})P(\overline{B})P(\overline{A})P(\overline{B})P(A) + \ldots.$$

$$= \frac{1}{6} + \frac{5}{6} \cdot \frac{5}{6} \cdot \frac{1}{6} + \frac{5}{6} \cdot \frac{5}{6} \cdot \frac{5}{6} \cdot \frac{5}{6} \cdot \frac{1}{6} \ldots..$$

$$= \frac{1}{6} + \left(\frac{5}{6}\right)^2 \cdot \frac{1}{6} + \left(\frac{5}{6}\right)^4 \cdot \frac{1}{6} \ldots$$

$$= \frac{\frac{1}{6}}{1 - \left(\frac{5}{6}\right)^2} = \frac{1}{6} \times \frac{36}{11} = \frac{6}{11}$$

Q. 28 The circuit shown in meant to supply a resistive load R_L from two separate DC voltage sources. The switches S_1 and S_2 are controlled so that only one of them is ON at any instant. S_1 is turned on for 0.2 ms and S_2 is turned on for 0.3 ms in a 0.5 ms switching cycle time period. Assuming continuous conduction of the inductor current and negligible ripple on the capacitor voltage, the output voltage V_0 (in Volt) across R_L is_____



Sol. 28 Correct answer is 7.

Given that only one of the two switches is ON at any instant.

For 0.2 ms, S_1 is ON and for 0.3 ms S_2 is ON. Here, we analyze the given circuit

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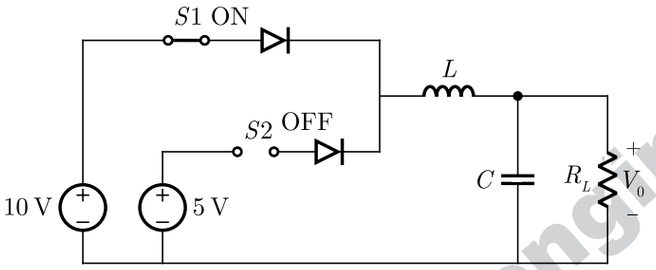
for the two cases:

CASE 1: For 0.2 ms

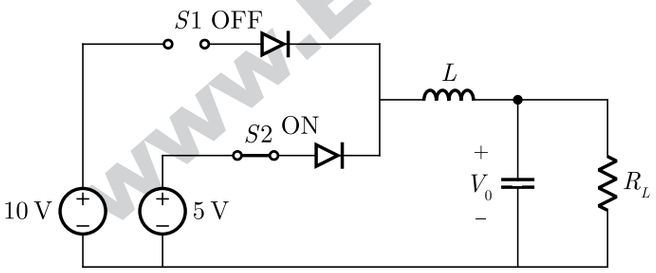
For this case, the circuit becomes as



So, the voltage 10 V appears across load resistor R_L for 0.2 ms cycle.

CASE 2: For 0.3 ms Cycle

For this case, the circuit becomes as



So, the voltage 5 V appears across load resistor R_L for 0.3 ms cycle.

Hence, we get the average output voltage as

$$V_0 = \frac{10 \times 0.2 + 5 \times 0.3}{0.5}$$

$$= 7 \text{ V}$$

Q. 29 Determine the correctness or otherwise of the following Assertion (A) and the Reason (R).

Assertion : Fast decoupled load flow method gives approximate load flow solution because it uses several assumptions.

Reason : Accuracy depends on the power mismatch vector tolerance.

(A) Both (A) and (R) are true and (R) is the correct reason for (A).

(B) Both (A) and (R) are true and (R) is not the correct reason for (A).

(C) Both (A) and (R) are false.

(D) (A) is false and (R) is true

Sol. 29 Correct option is (A).

In fast-decoupled load flow method, some terms are neglected to make gain faster.

For decoupled load flow, we have

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta |V|}{|V|} \end{bmatrix}$$

Here H, N, M, and L are elements of Jacobian. To make the system faster, we put

$$N = 0 \text{ and } M = 0$$

So, the resulting system is

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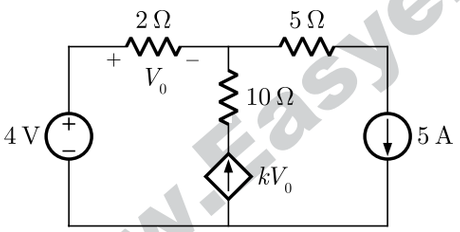
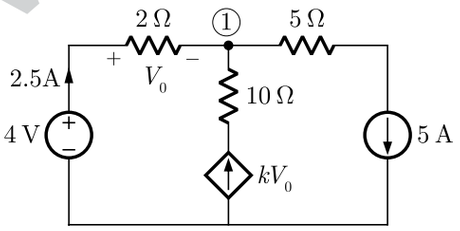
$$\begin{bmatrix} \triangle P \\ \triangle Q \end{bmatrix} = \begin{bmatrix} H & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} \triangle \delta \\ \frac{\triangle |V|}{|V|} \end{bmatrix}$$

This gives the approximate load flow gain.
Now, the statement given in Reason (R) is
Accuracy depends on the power mismatch vector tolerance.
As accuracy depend upon tolerance, so it is also correct.
Hence, both Assertion (A) and Reason (R) are correct but Reason (R) is not correct explanation of Assertion (A).

Q. 30 In the given circuit, the parameter k is positive, and the power dissipated in the $2\,\Omega$ resistor is 12.5 W. The value of k is _____



Sol. 30 Correct answer is 0.5
Given circuit is



Power dissipated in 2Ω resistor is 12.5 W, so

$$I_{2\Omega}^2 R = 12.5$$

or $$I_{2\Omega}^2 \times 2 = 12.5$$

or $$I_{2\Omega} = 2.5\,\Omega$$

Therefore, voltage across 2Ω resistor is

$$V_0 = IR$$
$$= 2.5 \times 2 = 5 \text{ V}$$

Applying KCL at node (1), we obtain

$$2.5 + kV_0 = 5$$
$$kV_0 = 5 - 2.5$$
$$kV_0 = 2.5$$
$$k \times 5 = 2.5$$

Hence, $$k = 0.5$$

Q. 31 In the signal flow diagram given in the figure, u_1 and u_2 are possible inputs whereas y_1 and y_2 are possible outputs. When would the SISO system derived from this diagram be controllable and observable?

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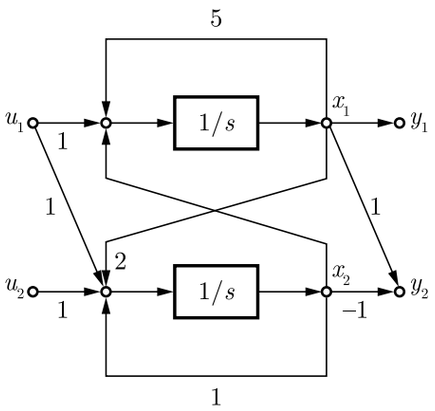


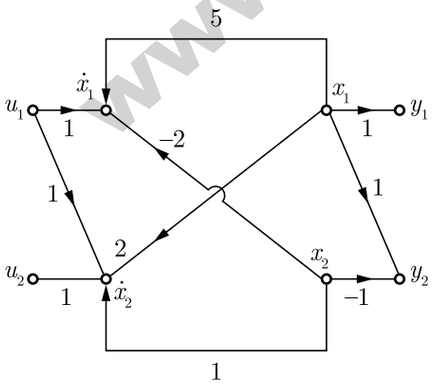
(A) When u_1 is the only input and y_1 is the only output.

(B) When u_2 is the only input and y_1 is the only output.

(C) When u_1 is the only input and y_2 is the only output.

(D) When u_2 is the only input and y_2 is the only output.

Sol. 31 Correct option is (B).



From the signal flow graph, we have

$$\dot{x}_1 = u_1 + 5X_1 - 2X_2$$

$$\dot{x}_2 = u_2 + u_1 + 2X_1 + X_2$$

$$y_1 = X_1$$

$$y_2 = -X_2 + X_1$$

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}5 & -2\\ 2 & 1\end{bmatrix}\begin{bmatrix}X_1\\ X_2\end{bmatrix} + \begin{bmatrix}1 & 0\\ 1 & 1\end{bmatrix}\begin{bmatrix}u_1\\ u_2\end{bmatrix}$$

$$\begin{bmatrix}y_1\\ y_2\end{bmatrix} = \begin{bmatrix}1 & 0\\ 1 & -1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

If u_1 is zero, u_2 is only input, and y_1 is only output. Then, the above expression becomes

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}5 & -2\\ 2 & 1\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}0\\ 1\end{bmatrix}\begin{bmatrix}u_2\end{bmatrix}$$

and

$$y_1 = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

To check the controllability, we form the matrix as

$$[B : AB] = \begin{bmatrix}0 & -2\\ 1 & 1\end{bmatrix}$$

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Since, determinant of the above matrix is 2 ($\neq 0$), so its rank will be 2, i.e. equal to the number of variables. Hence, the system is controllable.
Again, to check the observability of the system, we form the matrix

$$[C : CA] = \begin{bmatrix} 1 & 0 \\ 54 & -2 \end{bmatrix}$$

Determinant of the above matrix is -2 ($\neq 0$), so its rank will be 2, i.e. equal to the number of variables. Hence, the system is observable.
Thus, the given system is controllable and observable when u_2 is only input and y_1 is only output.

Q. 32 In a linear two-port network, when 10 V is applied to Port 1, a current of 4 A flows through Port 2 when it is short-circuited. When 5 V is applied to Port 1, a current of 1.25 A flows through a 1 Ω resistance connected across Port 2. When 3 V is applied to Port 1, then current (in Ampere) through a 2 Ω resistance connected across Port 2 is _____

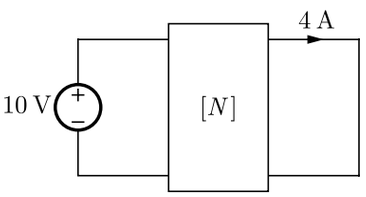
Sol. 32 Correct answer is 0.545
In two port network, Y-parameters are obtained for short circuited conditions. So, we will obtain the Y-parameters for the given problem. For two port network, we define the Y-parameters as

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$

and

$$I_2 = Y_{21} V_1 + Y_{22} Y_2$$

From the given problem, we draw the network for first condition



$$V_2 = 0,\ I_2 = 4 \text{ A},\ V_1 = 10 \text{ V}$$

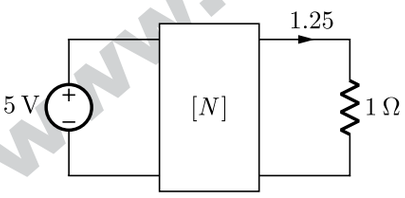
So,

$$4 = Y_{21} \times 10$$

or

$$Y_{21} = \frac{4}{10} = 0.4 \text{ mho}$$

Again, from the given data, we draw the network for second condition



So,

$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

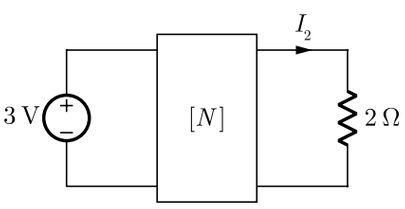
or

$$1.25 = 2 + Y_{22}(I \times 1.25)$$

or

$$Y_{22} = -0.6$$

Now, if 3 V is applied, the two port network becomes



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So, we obtain the current through the $2\,\Omega$ resistance as

$$I_2 = Y_{21}\,V_1 + Y_{22}\,V_2$$

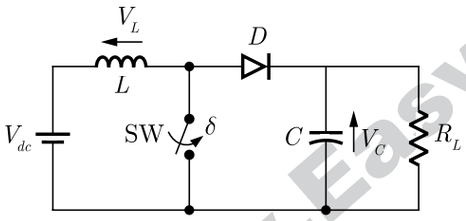
or $$I_2 = 0.4 \times 3 + (-0.6) \times V_2$$

or $$I_2 = 0.4 \times 3 - 0.6 \times 2 \times I_2 \qquad (V_2 = 2I_2)$$

or $$(1 + 1.2)I_2 = 1.2$$

Hence, $$I_2 = \frac{1.2}{2.2} = 0.545 \text{ A}$$

Q. 33 A self commutating switch SW, operated at duty cycle δ is used to control the load voltage as shown in the figure.



Under steady state operating conditions, the average voltage across the inductor and the capacitor respectively, are

(A) $V_L = 0$ and $V_c = \frac{1}{1-\delta}\,V_{dc}$

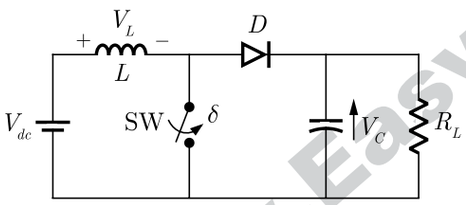
(B) $V_L = \frac{\delta}{2}\,V_{dc}$ and $V_c = \frac{1}{1-\delta}\,V_{dc}$

(C) $V_L = 0$ and $V_c = \frac{\delta}{1-\delta}\,V_{dc}$

(D) $V_L = \frac{\delta}{2}\,V_{dc}$ and $V_c = \frac{\delta}{1-\delta}\,V_{dc}$

Sol. 33 Correct option is (A).

Given circuit is



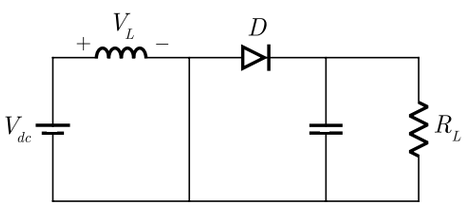
This is boost chopper, so output voltage across capacitor is

$$V_0 = \frac{V_{dc}}{1-\delta}$$

Now, we obtain the average voltage across inductor.

CASE I: When SW is ON

For this condition, diode is OFF, and all V_{dc} is applied across V_L.



CASE 2: When SW is OFF

For this condition, diode is ON, and we have

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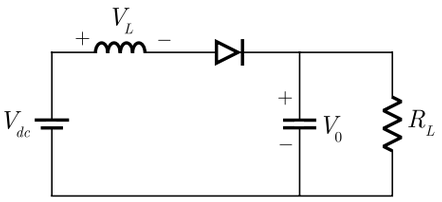
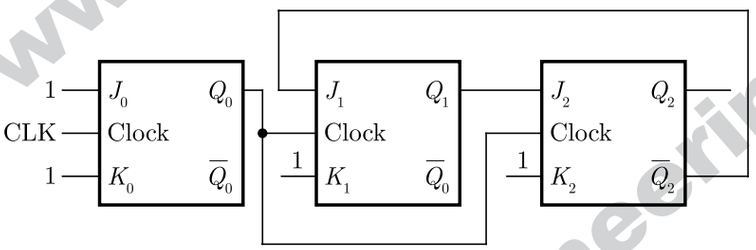
$$V_L = V_{dc} - V_0$$



Hence, the average inductor voltage is

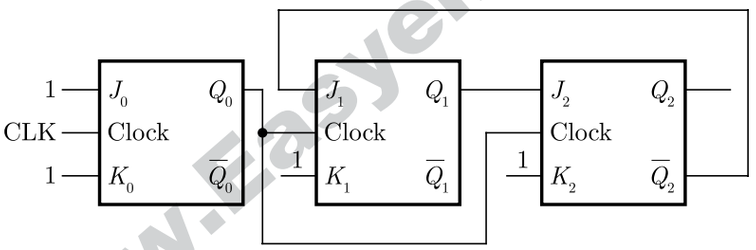
$$\begin{aligned} &= V_{dc} \times \delta + (V_{dc} - V_0)(1-\delta) \\ &= V_{dc}(\delta + 1 - \delta) - V_0(1-\delta) \\ &= V_{dc} \cdot 1 - V_0(1-\delta) \\ &= V_{dc} \cdot 1 - \frac{V_{dc}}{(1-\delta)}(1-\delta) \qquad \left(V_0 = \frac{V_{dc}}{1-\delta}\right) \\ &= 0 \text{ V} \end{aligned}$$

Q. 34 The figure shown a digital circuit constructed using negative edge triggered J-K flip flops. Assume a starting state of $Q_2 Q_1 Q_0 = 000$ will repeat after _____ number of cycles of the clock CLK.



Sol. 34 Correct answer is 6.

Given sequential circuit is



Here, all the three flip-flops are negative edge triggered. Initially, we have

$$Q_2 Q_1 Q_0 = 000$$

So, we obtain the truth table for the circuit as

	J_0	K_0	J_1	K_1	J_2	K_2	Q_2	Q_1	Q_0
	1	1	_	_	_	_	0	0	0
1 cycle	1	1	1	1	0	1	0	1	1
2 cycle	1	1	1	1	1	1	1	0	0
3 cycle	1	1	0	1	1	1	0	0	1
4 cycle	1	1	1	1	0	1	0	1	0
5 cycle	1	1	1	1	1	1	1	0	1
6 cycle	1	1	0	1	0	1	0	0	0

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From truth table, it is clear that the flip-flop is reset after 6th cycle; i.e. $Q_2\,Q_1\,Q_0$ becomes 000. Hence, the starting state repeats after 6 number of cycles of clock CLK.

Q. 35 The signum function is given by

$$\text{sgn}(x) = \begin{cases} \frac{x}{|x|}; x \neq 0 \\ 0; x = 0 \end{cases}$$

The Fourier series expansion of $\text{sgn}(\cos(t))$ has

(A) only sine terms with all harmonics.

(B) only cosine terms with all harmonics

(C) only sine terms with even numbered harmonics.

(D) only cosine terms with odd numbered harmonics.

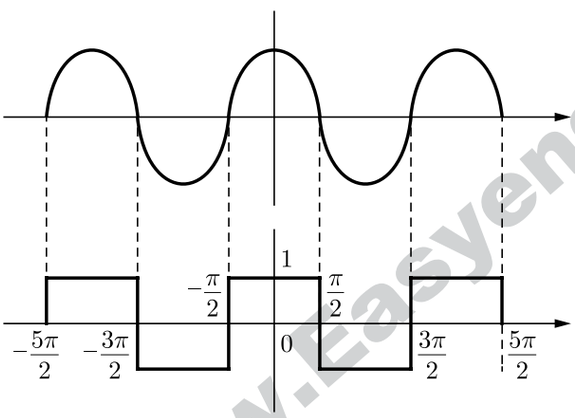
Sol. 35 Correct option is (D).

Given signum function $= \begin{cases} \frac{x}{|x|}; & \text{for } x \neq 0 \\ 0 & x = 0 \end{cases}$

$$\text{sgn}(\cos(t)) = \begin{cases} \frac{\cos t}{|\cos t|} & \cos t \neq 0 \\ 0 & \cos t = 0 \end{cases}$$

$$= \begin{cases} 1 & \cos t > 0 \\ -1 & \cos t < 0 \\ 0 & \cos t = 0 \end{cases}$$

So, we draw the waveform for the signal as



By graphical analysis, we conclude that the given function is even and half wave symmetric, and hence its Fourier series contains cosine term of all odd harmonics.

Q. 36 A DC motor has the following specifications: 10 hp, 37.5 A, 230 V;

flux/pole = 0.01 Wb,

number of poles = 4

number of conductors = 666

number of parallel paths = 2.

Armature resistance = 0.267 Ω.

The armature reaction is negligible and rotational losses are 600 W. The motor operates from a 230 V DC supply. If the motor runs at 1000 rpm, the output torque produced (in Nm) is_____

Sol. 36 Correct answer is 14.14

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Given specifications of D.C. motor,

$$10 \text{ hp}, 37.5 \text{ A}, 230 \text{ V},$$

$$\text{Flux/pole} = 0.01 \text{ Wb}.$$

$$P = 4,$$

$$Z = 666$$

$$\text{No. of parallel path } (A) = 2$$

$$r_a = 0.267$$

Since, armature reaction is negligible, so we have

$$\text{Rotation losses} = 600 \text{ W}$$

$$N = 1000 \text{ rpm}$$

$$E = \frac{P\phi ZN}{60A}$$

$$= \frac{4 \times 666 \times 0.01 \times 1000}{60 \times 2} = 55.5 \text{ V}$$

So, $P = EI$

$$= 55.5 \times 37.5 = 2081.25 \text{ w}$$

Therefore, $P_{\text{out}} = (\text{shaft power}) - (\text{rotational losses})$

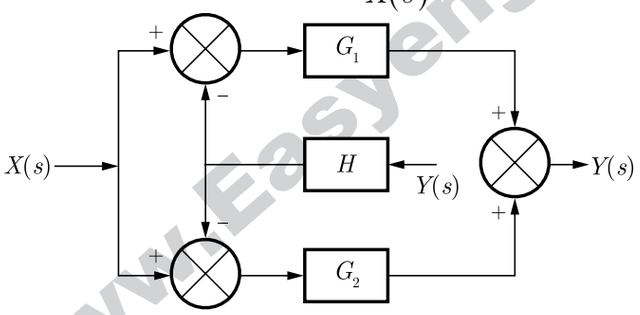
$$= 2081.25 - 600 = 1481.25 \text{ w}$$

Hence, $T = \frac{P_{\text{out}}}{\text{w}}$

$$= \frac{1481.25}{2\pi n_s}$$

$$= \frac{1481.25}{2 \times \pi \times \frac{1000}{60}} = 14.14 \text{ Nm}$$

Q. 37 Find the transfer function $\frac{Y(s)}{X(s)}$ of the system given below.



(A) $\frac{G_1}{1 - HG_1} + \frac{G_2}{1 - HG_2}$

(B) $\frac{G_1}{1 + HG_1} + \frac{G_2}{1 + HG_2}$

(C) $\frac{G_1 + G_2}{1 + H(G_1 + G_2)}$

(D) $\frac{G_1 + G_2}{1 - H(G_1 + G_2)}$

Sol. 37 Correct option is (C).

Given block diagram of the system,

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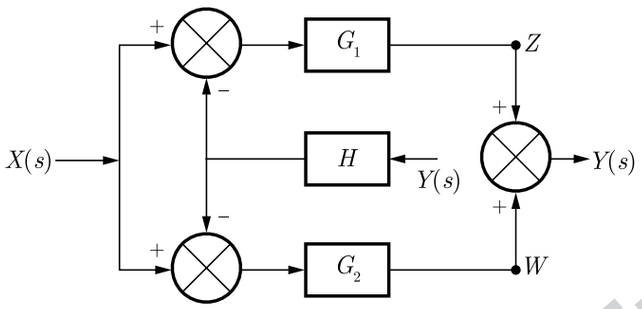


From the block diagram, we have

$$Z = (X(S) - HY(S))G_1 \quad (1)$$

$$W = (X(S) - HY(S))G_2 \quad (2)$$

Sum of Z and W is equal to Y, i.e.

$$Y(S) = Z + W$$

or $$Y = (X - HY)G_1 + (X - HY)G_2$$

or $$Y(1 + HG_1 + HG_2) = X(G_1 + G_2)$$

or $$\frac{Y}{X} = \frac{G_1 + G_2}{1 + G_1H + G_2H}$$

Hence, $$\frac{Y}{X} = \frac{G_1 + G_2}{1 + (G_1 + G_2)H}$$

Q. 38 The transfer function of a second order real system with a perfectly flat magnitude response of unity has a pole at $(2 - j3)$. List all the poles and zeroes.

(A) Poles at $(2 \pm j3)$, no zeroes

(B) Poles at $(\pm 2 - j3)$, one zero at origin.

(C) Poles at $(2 - j3), (-2 + j3)$, zeroes at $(-2 - j3), (2 + j3)$

(D) Poles at $(2 \pm j3)$, zeroes at $(-2 \pm j3)$

Sol. 38 Correct option is (D).

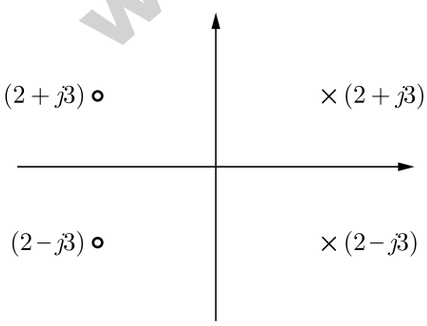
This is an all-pass filter. In this system, magnitude is always constant, and it is a second order real system. One pole of the system is given as

$$= (2 - j3)$$

For all pass filter, since roots are always in complex conjugate, so the other pole is

$$= (2 + j3)$$

Again, in all-pass system, for poles and zeros, only sign is changed but magnitude does not change. So, zero should be just right side of $s = 0$ plane at same distance of pole from $s = 0$ plane. Hence, we obtain the pole zero plot for the system as



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Q. 39 Two single-phase transformers T_1 and T_2 each rated at 500 kVA are operated in parallel. Percentage impedances of T_1 and T_2 are $(1+j6)$ and $(0.8+j4.8)$, respectively. To share a load of 1000 kVA at 0.8 lagging power factor, the contribution of T_2 (in kVA) is_____

Sol. 39 Correct answer is 555.

Rating of each single phase transformer is 500 kVA, and they operate in parallel. Also, we have

Percentage impedance of $T_1 = 1 + j6$

Percentage impedance of $T_2 = 0.8 + j4.8$

Now, we have to determine contribution of T_2 to share a load of 1000 kVA at 0.8 lags P.F.

When transformer are in parallel, the load shared by the transformer is inversely proportional by the transformer is inversely proportional to the percentage impedance, i.e.

$$S_1 \propto \frac{1}{Z_1}$$

so,
$$\frac{S_2}{S_1} = \frac{Z_1}{Z_2}$$

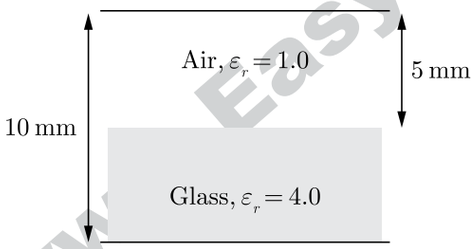
or
$$S_2 = \frac{S\,Z_2}{Z_1 + Z_2} = \frac{S\,Z_1}{Z_1 + Z_2}$$

$$= 1000\underline{/-\cos^{-1}(0.8)} \times \frac{1+j6}{1+0.8+j(6+4.8)}$$

$$= 1000\underline{/-36.86} \times \frac{1+j6}{1.8+j10.8}$$

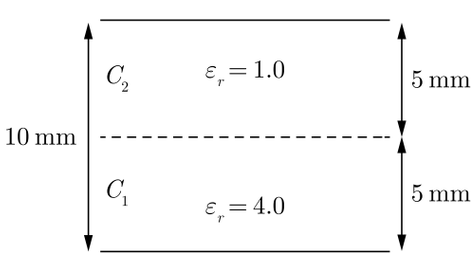
Hence, $S_2 = 555$ kVA.

Q. 40 A parallel plate capacitor is partially filled with glass of dielectric constant 4.0 as shown below. The dielectric strengths of air and glass are 30 kV/cm and 300 kV/cm, respectively. The maximum voltage (in kilovolts), which can be applied across the capacitor without any breakdown, is _____



Sol. 40 Correct answer is 18.75

Given parallel plate capacitor arrangement,



For the capacitor, we define

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$$C_1 = \frac{\varepsilon_1 \varepsilon_0 A}{d} = \frac{4\varepsilon_0 A}{d}$$

$$C_2 = \frac{\varepsilon_0 \varepsilon_2 A}{d} = \frac{\varepsilon_0 A}{d}$$

So, equivalent capacitance is

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = \frac{4A\varepsilon_0}{5d}$$

The electric field density (D_n) will not be affected by dielectric, so it will be same in both the medium. Therefore, we obtain

$$D_n = \rho_s = \frac{Q}{A} = \frac{CV}{A}$$

$$= \frac{4A\varepsilon_0}{5d} \times \frac{V}{A} = \frac{4\varepsilon_0 V}{5d}$$

This electric filed density will be same in both the mediums. Given the dielectric strength of two mediums,

Dielectric strengths of air = 30 kV/cm

Dielectric strength of glass = 300 kV/cm

So, dielectric breakdown will occur first in air medium. Therefore, we obtain the maximum voltage (before breakdown) as

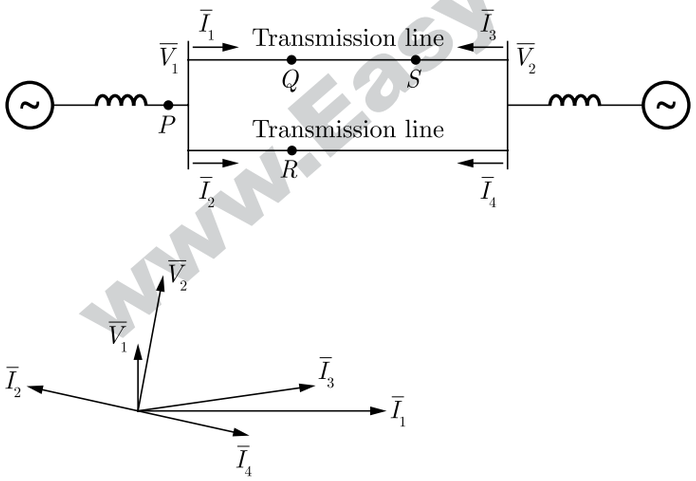
$$E_2 = \frac{D_n}{\varepsilon_0} = \frac{4V}{5d}$$

or $$30\ \text{kV/cm} = \frac{4V}{5d}$$

Hence, $$V = \frac{5 \times (30 \times 10^2)(5 \times 10^{-3})}{4}$$

$$= 18.75\ \text{kV}$$

Q. 41 A sustained three-phase fault occurs in the power system shown in the figure. The current and voltage phasors during the fault (on a common reference), after the natural transients have died down, are also shown. Where is the fault located?



(A) Location P

(B) Location Q

(C) Location R

(D) Location S

Sol. 41 Correct option is (D).

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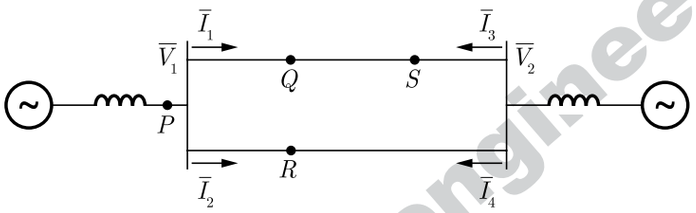
In the given phasor diagram, we can observe that all the current except I_2 are lagging in nature. In the power system, if there is any fault, then current always lagging in nature because mostly line are inductive in nature. If current is leading, I_2 will be opposite in direction that shown in figure. So, we get the actual current direction flow diagram as



Hence, fault should be at point Q only.
In other case, if fault is at point s, then current I_2 and I_4 will flow in the direction R-S-Q.

Q. 42 The maximum value of "a" such that the matrix $\begin{pmatrix} -3 & 0 & -2 \\ 1 & -1 & 0 \\ 0 & a & -2 \end{pmatrix}$ has three linearly independent real eigenvectors is

(A) $\frac{2}{3\sqrt{3}}$

(B) $\frac{1}{3\sqrt{3}}$

(C) $\frac{1+2\sqrt{3}}{3\sqrt{3}}$

(D) $\frac{1+\sqrt{3}}{3\sqrt{3}}$

Sol. 42 Correct option is (B).
Given Matrix

$$A = \begin{bmatrix} -3 & 0 & -2 \\ 1 & -1 & 0 \\ 0 & a & -2 \end{bmatrix}$$

So, we write the characteristic equation for the matrix as

$$|A - \lambda I| = 0$$

or $$\begin{vmatrix} -3-\lambda & 0 & -2 \\ 1 & -1-\lambda & 0 \\ 0 & a & -2-\lambda \end{vmatrix} = 0$$

or $$(-3-\lambda)(-1-\lambda)(-2-\lambda) - 2a = 0$$

or $$(\lambda+3)(\lambda+2)(\lambda+1) + 2a = 0$$

or $$\lambda^3 + 6\lambda^2 + 11\lambda + 6 + 2a = 0$$

So, $$a = -\frac{\lambda^3}{2} - 3\lambda^2 - \frac{11}{2}\lambda - 3 \quad (1)$$

For maximum value of a, we have

$$\frac{da}{d\lambda} = \frac{-3\lambda^2}{2} - 6\lambda - \frac{11}{2} = 0$$

or $$3\lambda^2 + 12\lambda + 11 = 0$$

Solving the quadratic equation; we obtain

$$\lambda = \frac{-12 \pm \sqrt{144 - 4(3)(11)}}{2 \times 3}$$

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$$= -2 \pm \frac{1}{\sqrt{3}}$$

This is a real value. Now, checking the value for maxima

$$\frac{d^2a}{d\lambda^2} = -\frac{6\lambda}{2} - 6$$

$$= -3\left(-2 - \frac{1}{\sqrt{3}}\right) - 6 \qquad \left(\text{for } \lambda = -2 - \frac{1}{\sqrt{3}}\right)$$

$$= \sqrt{3} > 0$$

Again, we have

$$\frac{d^2a}{d\lambda^2} = -3\left(-2 + \frac{1}{\sqrt{3}}\right) - 6 \qquad \left(\text{for } \lambda = -2 + \frac{1}{\sqrt{3}}\right)$$

$$= -\sqrt{3} < 0$$

So, a will be maximum for

$$\lambda = -2 + \frac{1}{\sqrt{3}}$$

Substituting this value in equation (1) we get

$$a = -\frac{1}{2}\left(-2 + \frac{1}{\sqrt{3}}\right)^3 - 3\left(-2 + \frac{1}{\sqrt{3}}\right)^2 - \frac{11}{2}\left(-2 + \frac{1}{\sqrt{3}}\right) - 3$$

$$= -\frac{1}{2}\left(-8 + \frac{1}{3\sqrt{3}} + \frac{12}{\sqrt{3}} - 2\right) - 3\left(4 + \frac{1}{3} - \frac{4}{\sqrt{3}}\right) + 11 - \frac{11}{2\sqrt{3}} - 3$$

$$= 4 - \frac{1}{6\sqrt{3}} - \frac{6}{\sqrt{3}} + 1 - 12 - 1 + 4\sqrt{3} + 8 - \frac{11}{2\sqrt{3}}$$

$$= -\frac{1}{6\sqrt{3}} + 2\sqrt{3} - \frac{11}{2\sqrt{3}}$$

$$= \frac{-1 + 36 - 33}{6\sqrt{3}} = \frac{2}{6\sqrt{3}} = \frac{1}{3\sqrt{3}}$$

Q. 43 The open loop poles of a third order unity feedback system are at $0, -1, -2$. Let the frequency corresponding to the point where the root locus of the system transits to unstable region be K. Now suppose we introduce a zero in the open loop transfer function at -3, while keeping all the earlier open loop poles intact. Which one of the following is TRUE about the point where the root locus of the modified system transits to unstable region?

(A) It corresponds to a frequency greater than K

(B) It corresponds to a frequency less than K

(C) It corresponds to a frequency K

(D) Root locus of modified system never transits to unstable

Sol. 43 Correct option is (D).

Before adding zero in the system, open loop T.F. of the system is

$$G(s)H(s) = \frac{K_1}{s(s+1)(s+2)}$$

$$q(s) = 1 + G(s)x(s)$$

$$= s(s+1)(s+2) + K_1 = 0$$

$$= s^3 + 3s^2 + 2s + K_1 = 0$$

We check the stability of the system by Routh criteria. The routh array is shown below.

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s^3	1	2
s^2	3	K_1
s	$\frac{6-K_1}{3}$	0
s^0	K_1	0

For the system to be unstable (i.e. root locus cross the imaginary axis), we have

$$\frac{6-K_1}{3} \leq 0$$

or $$K_1 \geq 6$$

Now, adding zero to the system, we have

$$G(s)H(s) = \frac{K_1(s+3)}{s(s+1)(s+2)}$$

So,
$$\begin{aligned} q(s) &= 1 + G(s)H(S) \\ &= s^3 + 3s^2 + 2s + K_1 s + 3K_1 \\ &= s^3 + 3s^2 + (1+K_1)s + 3K_1 \\ &= s^3 + 3s^2 + (K_1+2)s + 3K_1 \end{aligned}$$

Routh array for the characteristic equation is obtained as

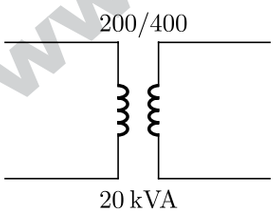
s^3	1	K_1+2
s^2	3	$3K_1$
s^1	2	0
s^0	$3K_1$	0

In the Routh array, for any value of $K_1 \geq 6$, system does not go in right half cycle of $s=0$ plane and in negative feed back system, dc gain is always positive. So, it is always stable. Hence, the root locus of modified system never transits to unstable region.

Q. 44 A 200/400 V, 50 Hz, two-winding transformer is rated at 20 kVA. Its windings are connected as an auto-transformer of rating 200/600 V. A resistive load of 12 Ω is connected to the high voltage (600 V) side of the auto-transformer. The value of equivalent load resistance (in Ohm) as seen from low voltage side is_____

Sol. 44 Correct answer is 1.33

Given 200/400 V two-winding transformer has rating of 20 kVA and 50 Hz.



Now, the windings are connected as an auto transformer of rating 200/600 V.

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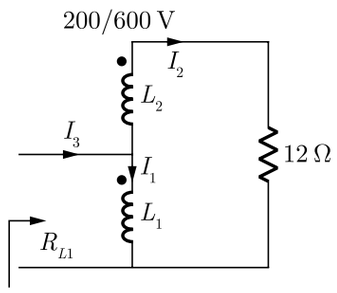

From the transformer circuit, we have

$$\text{Current in } L_1 \text{ winding} = \frac{20 \times 10^3}{200} = 100 \text{ A}$$

$$\text{Current in } L_2 \text{ winding} = \frac{20 \times 10^3}{400} = 50 \text{ A}$$

So, $$I_3 = I_1 + I_2 = 100 + 50 = 150 \text{ A}$$

Resistance losses in both the cases should be same, so

$$I_2^2 R_2 = I_3^2 R_{e1}$$

or $$(50)^2 \times 12 = (150)^2 R_{e1}$$

Hence, $$R_{e1} = \frac{12 \times (50)^2}{(150)^2} = 1.33\,\Omega$$

Q. 45 Consider the economic dispatch problem for a power plant having two generating units. The fuel costs in Rs/MWh along with the generation limits for the two units are given below:

$$C_1(P_1) = 0.01P_1^2 + 30P_1 + 10;\ 100 \text{ MW} \le P_1 \le 150 \text{ MW}$$

$$C_2(P_2) = 0.05P_2^2 + 10P_2 + 10;\ 100 \text{ MW} \le P_2 \le 180 \text{ MW}$$

The incremental cost (in Rs/MWh) of the power plant when it supplies 200 MW is _____

Sol. 45 Correct answer is 0.

Given fuel costs,

$$C_1(P_1) = 0.01P_1^2 + 30P_1 + 10 \qquad \text{where } 100 \le P_1 \le 150$$

$$C_2(P_2) = 0.05P_2^2 + 10P_2 + 10 \qquad \text{where } 100 \le P_2 \le 180$$

Total load, $$P_D = 200 \text{ MW}$$

So, $$P_1 + P_2 = 200 \qquad (1)$$

For economical scheduling, the required condition is

$$\frac{dC_1}{dP_1} = \frac{dC_2}{dP_2}$$

Now, we have

$$\frac{dC_1}{dP_1} = 0.02P_1 + 30 \qquad (2)$$

and $$\frac{dC_2}{dP_2} = 0.1P_2 + 10 \qquad (3)$$

On equating the above equations,

$$0.2P_1 + 30 = 0.1P_2 + 10$$

or $$2P_1 + 3000 = 10P_2 + 1000$$

or $$5P_2 - P_1 = 1000 \qquad (4)$$

On solving equations (1) and (4), we get

$$P_2 = 200, \text{ and } P_1 = 0$$

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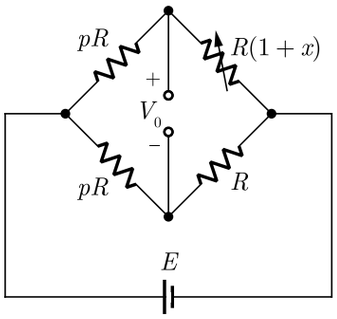
Q. 46 An unbalanced DC Wheatstone bridge is shown in the figure. At what value of p will the magnitude of V_0 be maximum ?



(A) $\sqrt{(1+x)}$

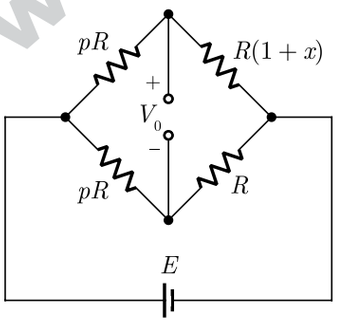
(B) $(1+x)$

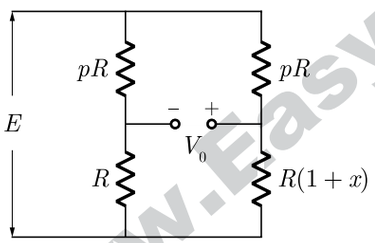
(C) $\dfrac{1}{\sqrt{(1+x)}}$

(D) $\sqrt{(1-x)}$

Sol. 46 Correct option is (A).

Given circuit is redrawn as





From the circuit, we obtain

$$V_{0(+)} = \frac{ER(1+x)}{pR + R(1+x)} = \frac{E(1+x)}{p+(1+x)}$$

and $$V_{0(-)} = \frac{ER}{pR+R} = \frac{E}{P+1}$$

So, the output voltage is

$$V_0 = V_{0(+)} - V_{0(-)} = \frac{E(1+x)}{p+1+x} - \frac{E}{p+1}$$

The magnitude of V_0 is maximum for

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$$\frac{dV_0}{dp} = 0$$

or $$\frac{-E(1+x)}{(p+1+x)^2} + \frac{E}{(p+1)^2} = 0$$

or $$\frac{(1+x)}{(p+1+x)^2} = \frac{1}{(p+1)^2}$$

or $$(\sqrt{1+x})(p+1) = p + (1+x)$$

or $$(\sqrt{1+x} - 1)p = (1+x) - \sqrt{1+x}$$

Hence, $$p = \frac{\sqrt{1+x}(\sqrt{1+x}-1)}{(\sqrt{1+x}-1)}$$

$$= \sqrt{1+x}$$

Q. 47 A separately excited DC motor runs at 1000 rpm on no load when its armature terminals are connected to a 200 V DC source and the rated voltage is applied to the field winding. The armature resistance of this motor is 1 Ω. The no-load armature current is negligible. With the motor developing its full load torque, the armature voltage is set so that the rotor speed is 500 rpm. When the load torque is reduced to 50% of the full load value under the same armature voltage condition, the speed rises to 520 rpm. Neglecting the rotational losses, the full load armature current (in Ampere) is_____

Sol. 47 Correct answer is 8.

Q. 48 A solution of the ordinary differential equation $\frac{d^2y}{dt^2} + 5\frac{dy}{dt} + 6y = 0$ is such that $y(0) = 2$ and $y(1) = -\frac{1-3e}{e^3}$. The value of $\frac{dy}{dt}(0)$ is_____

Sol. 48 Correct answer is -3.

Given differential equation,

$$\frac{d^2y}{dt^2} + 5\frac{dy}{dt} + 6y = 0$$

So, the auxiliary equation can be solved as

$$(m^2 + 5m + 6)y = 0$$

$$m^2 + 5m + 6 = 0$$

or $$m = -2, -3$$

Therefore, the solution of differential equation will be of the form

$$y(t) = C_1 e^{-2t} + C_2 e^{-3t} \quad (1)$$

Given $$y(1) = -\frac{(1-3e)}{e^3}$$

and $$y(0) = 2$$

Substituting $t = 0$ in equation (1),

$$y(0) = C_1 + C_2 = 2$$

or $$C_1 + C_2 = 2 \quad (2)$$

Again, substituting $t = 1$ in equation (1),

$$y(1) = C_1 e^{-2} + C_2 e^{-3}$$

or $$\frac{3e^{-1}}{e^3} = \frac{C_1 e + C_2}{e^3} \quad (3)$$

Solving equations (2) and (3), we get

$$C_1 = 3$$

$$C_2 = -1$$

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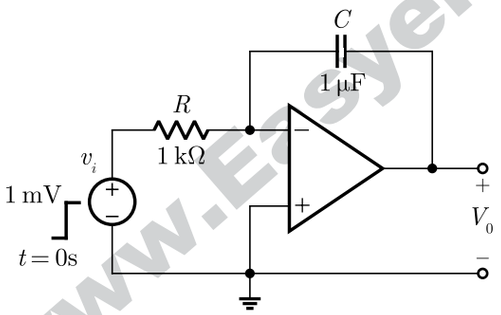
Hence, $y(t) = 3e^{-2t} + 3e^{-3t}$

and $\left.\frac{dy(t)}{dt}\right| = -6e^{-2t} + 3e^{-3t}$

Thus, at $t = 0$, we obtain

$$\frac{dy}{dt}(0) = -6 + 3 = -3$$

Q. 49 The op-amp shown in the figure has a finite gain $A = 1000$ and an infinite input resistance. A step-voltage $V_i = 1$ mV is applied at the input at time $t = 0$ as shown. Assuming that the operational amplifier is not saturated, the time constant (in millisecond) of the output voltage V_0 is



(A) 1001

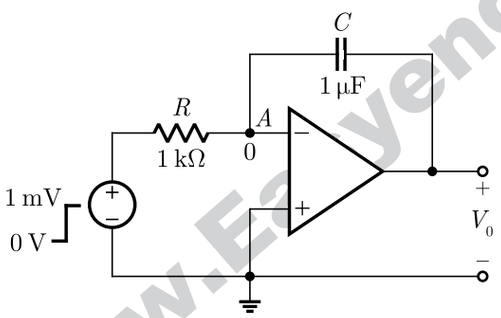
(B) 101

(C) 11

(D) 1

Sol. 49 Correct option is (D).

We redraw the given circuit as



Applying nodal analysis at node A,

$$\frac{0 - \frac{1}{s}(1 \times 10^{-3})}{R} + \frac{0 - V_0}{\frac{1}{Cs}} = 0$$

or $$\frac{1}{sR}(1 \times 10^{-3}) = -CsV_0$$

or $$V_0 = -\frac{1}{CRs^2}(1 \times 10^{-3})$$

From above equation, the time constant of circuit is obtained as

$$\begin{aligned}\tau &= RC \\ &= 1 \times 10^3 \times 1 \times 10^{-6} \\ &= 1 \text{ millisecond}\end{aligned}$$

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Q. 50 A 3-phase 50 Hz square wave (6-step) VSI feeds a 3-phase, 4 pole induction ,motor. The VSI line voltage has a dominant 5^{th} harmonic component. If the operating slip of the motor with respect to fundamental component voltage is 0.04 the slip of the motor with respect to 5^{th} harmonic component of voltage is_____

Sol. 50 Correct answer is 5.8

For the 3-phase, 4 pole, 50 Hz induction motor, we have

$$\text{Synchronous speed} = n_s = \frac{120f}{P}$$

$$= \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

The operating slip is given by

$$s = \frac{N_s - N}{N_s}$$

So, $$0.04 = 1 - \frac{N}{N_s}$$

or $$N = N_s(1 - 0.04)$$

$$= 1500 \times 0.96 = 1440 \text{ rpm}$$

Since, fifth harmonic component is negative sequence component. So, it rotates in negative direction.

$$N_5 = 5N \qquad [\text{since } N = \tfrac{120f}{P}, N_5 = \tfrac{120 \times (5f)}{P}]$$

Hence, slip with respect to fifth harmonic is

$$s = \frac{N_s - (-5N)}{N_s}$$

$$= \frac{N_s + 5N}{N_s}$$

$$= \frac{1500 + 5 \times 1440}{1500} = 5.8$$

Q. 51 An 8 bit unipolar Successive Approximation Register type ADC is used to convert 3.5 V to digital equal output. The reference voltage is +5 V. The output of ADC at end of 3^{rd} clock pulse after the start of conversion is

(A) 10100000

(B) 10000000

(C) 00000001

(D) 00000011

Sol. 51 Correct option is (A).

In successive approximation DAC, at even clock pulse, it will load a value in output register with MSB = 1 and remaining bit will be unchanged.

If $V_{in} < V_{DAC}$, then it maintains the loaded bit

$V_{in} < V_{DAC}$, then it clears the loaded bit

Now, the resolution is given by

$$R = \frac{V_{max}}{2^n - 1} = \frac{5}{2^8 - 1} = 20 \text{ mV}$$

For the first clock pulse, the value loaded in register is

$$= (10000000)_2 = (128)_{10}$$

So, $$V_{DAC} = 128 \times 20 \text{ mV} = 2.56 \text{ V}.$$

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Therefore, we have

$$V_{\text{in}} > V_{DAC} \qquad (3.5 > 2.56)$$

So, it maintains the bit in second clock pulse. Again, it will load value in output register as

$$(11000000)_2 = (192)_{10}$$

So, $V_{DAC} = 192 \times 20\,\text{mV} = 3.84\ \text{V}$

For this, we have

$$V_{\text{in}} < V_{DAC} \qquad (3.5 < 3.84)$$

So, it will clear the bit in second cycle. So, after second cycle, the output is

$$= (10000000)_2 = (128)_{10}$$

Similarly, in third cycle, it will load bit in output register as

$$(10100000)_2 = (160)_{10}$$

and we obtain

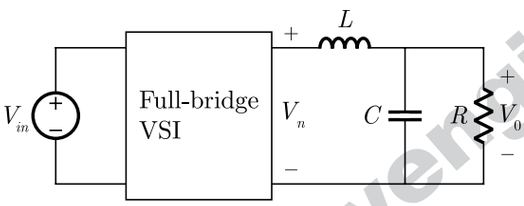
$$V_{DAC} = 160 \times 20 = 3.2\ \text{V}$$

Since, $V_{\text{in}} > 3.2\,\text{V}$

So, it maintains the loaded bit. Hence, at the end of third bit, we have

$$(10100000)_2 = (160)_{10}$$

Q. 52 The single-phase full-bridge voltage source inverter (VSI), shown in figure, has an output frequency of 50 Hz. It uses unipolar pulse width modulation with switching frequency of 50 kHz and modulation index of 0.7 for $V_m = 100\,\text{V}$ DC, $L = 9.55$ mH, $C = 63.66\,\mu\text{F}$, and $R = 5\,\Omega$, the amplitude of the fundamental component in the output voltage V_0 (in volt) under steady-state is_____



Sol. 52 Correct answer is 56.72

For the given VSI, we obtain the pulse width as

$$2d = 0.7 \times 180^\circ$$

or

$$d = \frac{0.7 \times 180^\circ}{2}$$

$$= 0.7 \times 90 = 63^\circ$$

So, output voltage is

$$V_0 = \sum_{n=1,3,5}^{\infty} \frac{4\,V_s}{\pi} \sin nd \sin \frac{n\pi}{2} \sin n\omega t$$

Hence, amplitude of fundamental voltage is

$$V_0 = \frac{V_s}{\pi} \sin d$$

$$= \frac{2 \times 100}{\pi} \sin 63^\circ$$

$$= 56.72$$

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Q. 53 $f(A,B,C,D) = \Pi\, M(0,1,3,4,5,7,9,11,12,13,14,15)$ is a maxterm representation of a Boolean function $f(A,B,C,D)$ where A is the *MSB* and D is the *LSB*. The equivalent minimized representation of this function is

(A) $(A+\overline{C}+D)(\overline{A}+B+D)$

(B) $A\overline{C}D+\overline{A}BD$

(C) $\overline{A}C\overline{D}+A\overline{B}C\overline{D}+A\overline{B}\overline{C}\overline{D}$

(D) $(B+\overline{C}+D)(A+\overline{B}+\overline{C}+D)(\overline{A}+B+C+D)$

Sol. 53 Correct option is (C).

Given maxterm representation,

$$f(A,B,C,D) = \Pi\, M(0,1,3,4,5,7,9,11,12,13,14,15)$$

So, the minterm representation for the Boolean function is

$$f(A,B,C,D) = \Sigma m(2,6,8,10)$$

Here, A is MSB and D is LSB, so we form the K-map as

AB \ CD	$\overline{C}\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\overline{B}$	0	0	0	1
$\overline{A}B$	0	0	0	1
AB	0	0	0	0
$A\overline{B}$	1	0	0	1

From the K-map, we have

$$f(A,B,C,D) = \overline{A}C\overline{D}+A\overline{B}\,\overline{D}$$

In option (C), the expression is

$$\begin{aligned} &= \overline{A}C\overline{D}+A\overline{B}\,\overline{D}+A\overline{B}\,\overline{C}\,\overline{D} \\ &= \overline{A}C\overline{D}+A\overline{B}\,\overline{D}(1+\overline{C}) \\ &= \overline{A}C\overline{D}+A\overline{B}\,\overline{D} \end{aligned}$$

This is same as that obtained from the K-map. Hence, the equivalent minimized representation of the given function is

$$\overline{A}C\overline{D}+A\overline{B}C\overline{D}+A\overline{B}C\overline{D}$$

Q. 54 A 50 Hz generating unit has H-constant of 2 MJ/MVA. The machine is initially operating in steady state at synchronous speed, and producing 1 pu of real power. The initial value of the rotor angle δ is 5°, when a bolted three phase to ground short circuit fault occurs at the terminal of the generator. Assuming the input mechanical power to remain at 1 pu, the value of δ in degrees, 0.02 second after the fault is_____

Sol. 54 Correct answer is 5.9

Given

$$\text{Inertia constant, } H = 2 \text{ MJ/MVA.}$$

$$\text{Initial rotor angle} = 5^\circ$$

$$P_m = 1 \text{ P.U.}$$

Here, mechanical momentum is

$$m = \frac{GH}{\pi f} = \frac{2}{180 \times 50} = \frac{1}{4500} \text{ P.U.}$$

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A bolted three phase to ground short circuit fault occurs at the terminal of the generator, so

$$m\alpha = P_m - P_c$$

or
$$\alpha = \frac{P_m - 0}{m} = \frac{1}{\frac{1}{4500}} = 4500 \text{ deg/sec}$$

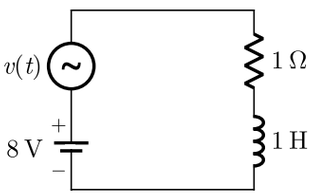
Hence, the change in angle is

$$\Delta\delta = \frac{1}{2} \times t^2$$
$$= \frac{1}{2} \times 4500 \times (0.02)^2$$
$$= 4500 \times 0.01 \times 0.02$$
$$= 9000 \times 10^{-4}$$
$$\Delta\delta = .9^\circ$$

After 0.02 sec, we have

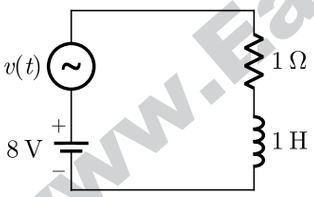
$$\delta = \delta_1 + \Delta\delta$$
$$= 5 + .9$$
$$\delta = 5.9^\circ$$

Q. 55 The circuit shown in the figure has two sources connected in series. The instantaneous voltage of the AC source (in volt) is given by $v(t) = 12\sin t$. If the circuit is in steady-state, then the rms value of the current (in Ampere) flowing in the circuit is_____



Sol. 55 Correct answer is 10.

Given circuit is



From the circuit, we have

$$v(t) = 12\sin t$$
$$z(s) = R + LS = 1 + 1s$$

or
$$z(j\omega) = (1 + j\omega)$$

So,
$$i(t) = \frac{8}{(1+j\omega)} + \frac{12\sin t}{(1+j\omega)} \quad (1)$$

Now, we have

$\omega = 0$ rad/sec, for dc voltage, $V_{dc} = 8$ V

$\omega = 1$ rad/sec, for $v(t) = 12\sin t$

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So, equation (1) becomes

$$i(t) = \frac{8}{\sqrt{1^2+0^2}}\underline{/-\tan^{-1}(0)} + \frac{12}{\sqrt{1^2+1^2}}\sin(t-45^\circ)$$

$$= 8 + \frac{12}{\sqrt{2}}\sin(t-45)$$

$$= 8 + \frac{12}{\sqrt{2}}\left(\sin + \frac{1}{\sqrt{2}} - \cos t\frac{1}{\sqrt{2}}\right)$$

$$i(t) = 8 + 6\sin t - 6\cos t$$

Hence, the rms value of current is

$$i_{\text{rms}} = \sqrt{8^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{6}{\sqrt{2}}\right)^2} = 10 \text{ A}$$

END OF THE QUESTION PAPER

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ANSWER KEY

General Aptitude									
1	2	3	4	5	6	7	8	9	10
(B)	(A)	(C)	(A)	(A)	(A)	(B)	(32)	(C)	(D)

Electrical Engineering									
1	2	3	4	5	6	7	8	9	10
(90)	(0.192)	(9)	(A)	(3.36)	(D)	(D)	(A)	(0.25)	(A)
11	12	13	14	15	16	17	18	19	20
(B)	(1)	(C)	(B)	(A)	(B)	(A)	(A)	(A)	(D)
21	22	23	24	25	26	27	28	29	30
(B)	(105.1)	(0.22)	(A)	(A)	(C)	(D)	(7)	(A)	(0.5)
31	32	33	34	35	36	37	38	39	40
(B)	(0.545)	(A)	(6)	(D)	(14.14)	(C)	(D)	(555)	(18.75)
41	42	43	44	45	46	47	48	49	50
(D)	(B)	(D)	(1.33)	(0)	(A)	(8)	(–3)	(D)	(5.8)
51	52	53	54	55					
(A)	(56.72)	(C)	(5.9)	(10)					

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